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CREATIONS has received funding from the European Commission HORIZON2020 Programme

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Annex 1: CREATIONS Demonstrators

D3.2.1 UBT Bionics – out-of-school learning in the zoo

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Michaela Marth (UBT)
Code:	D 3.2.1	**Contributors:**	Dr. Cathérine Conradty (UBT)
Version & Date:	**V2**	**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Bionics – out-of-school learning in the zoo:

The intervention provides selected bases around the theme of bionics and their diversity.

1.2 Type of Activity

Educational activities based on Creativity- enriched Inquiry Based approaches A day in the zoo shows different aspects of bionic. These aspects are presented in a big learning circle included some handicraft work, hands- on stations and guided learning.

1.3 Duration

One day per class. All in all 16 classes included.

1.4 Setting (formal / informal learning)

Informallearning is located in different scenarios in the zoo. These activities are guided by trained employees in the zoo.

1.5 Effective Learning Environment

The learning scenarios are located in the zoo in Nuremberg. In the zoo there are different stations where the students could learn about bionic and train individual skills.

- Simulations of the streamline shaped animals are shown in the learning scenarios, which should be visualizing the theoretical model of the moving problem in the water. Inquiry based experiments should be brought in classroom or even in the zoo.

- Art based learning scenarios are located in the zoo with the handicraft work for the Fin Ray-Effect ® and some more practical experiments in the exhibition next to the zoo.
- Dialogic space is given in the zoo special argumentation hour. The students can talk to experts and learn from their experience in science and also communicate about problems in the zoo and the bionic topics which are linked with that.
- Experimentations are made with the students directly on the compound. They learn through 'hands on' stations in different bionic topics.
- Communication of scientific ideas is also given in the special talking round with the experts and scientists directly in the zoo.

2. Rational of the Activity / Educational Approach

2.1 Challenge

There are so much wrong perceptions about bionic or even NO perception about bionic topics. So the children should solve these problems with thinking about different everyday examples they know.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The students should do some handicrafts work in the different stations in the zoo. With these skills they should learn more about the technical literacy and examples of bionics. Many examples are given in the different stations. In Addition to that they should draw shown experiments to save the information with multisensory learning. Through such learning activities the creative aspects are trained in different ways. The CREATIONS framework finally gives the framework of this learning out of school in the zoo.

3. Learning Objectives

3.1 Domain specific objectives

Pilot study: Perceptions about technic from students, university freshman and teachers

Research of the reliability of the existing Technology Questionnaire (Rennie & Harding , 1992)

Is there an increase of knowledge due to the intervention? Correlates the increase of knowledge with the motivation for technology?

Is the scientific motivation of children who are interested in technology bigger than by less interested students?

Is there an influence of cognitive load (CL) and technical motivation during the learning unit? Is there an influence of certain personality traits?

3.2 General skills objectives

Handicraft should be a big topic in these learning scenarios. The children should work with the hands to learn not only with the eyes. The topic of this skill is "learning by doing". The children should learn bionic topics in different ways. Learning is not mediated as in school. There is a new way teaching students and looking for students' problems and alternative perceptions.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Research-based learning (Inquiry Based Science Education) plays a major role in science education (Bogner & Sotiriou, 2011).

In cooperation with the "BIONICUM" at the zoo in Nuremberg a curriculum compliant learning circle about Bionics was established (6th grade).

The intervention provides selected bases around the theme of bionics and their diversity.

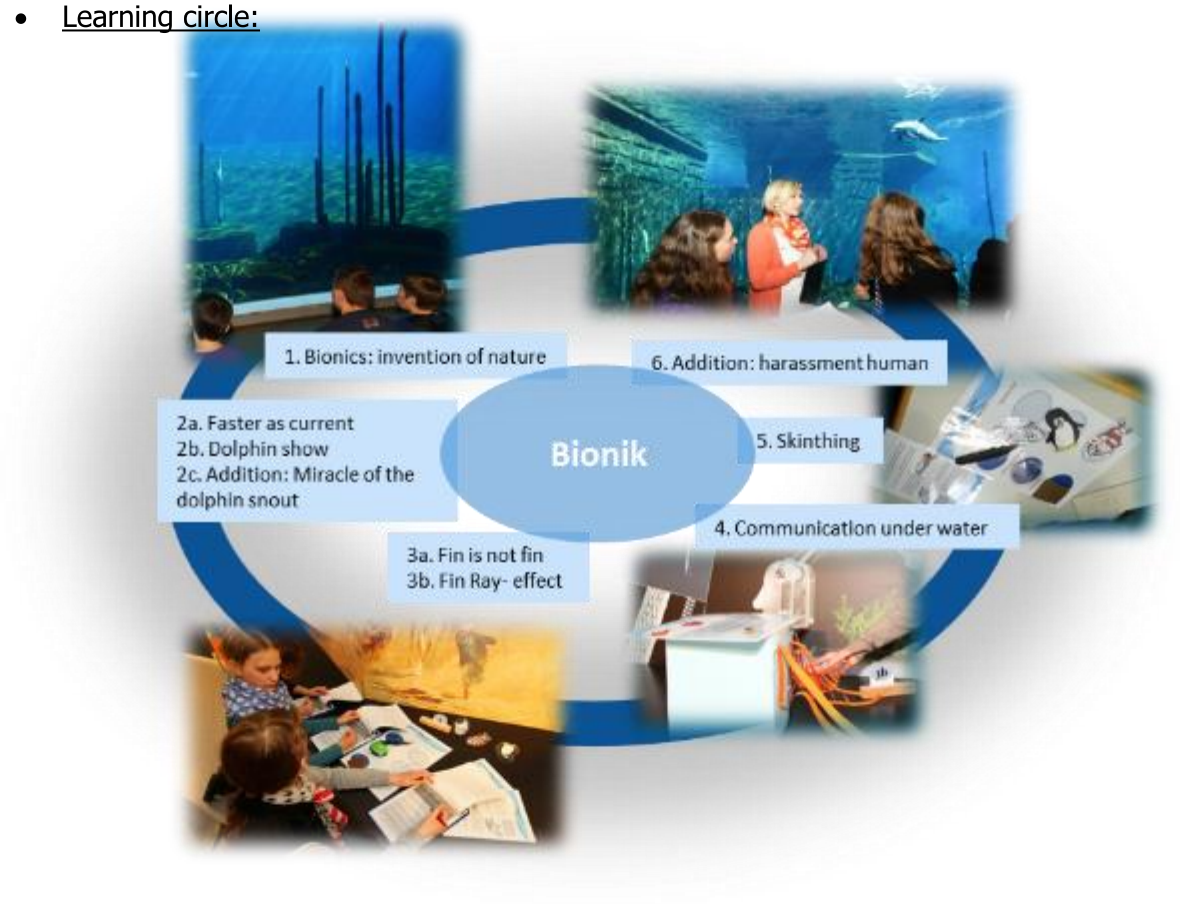
Students gain an overview about different bionic areas and learn the bionics concept and its importance to know.

4.2 Student needs addressed

Students should bring some skills in the learning circle. They should have perception about technical topics, technical interest and social aspects of technology. This together with handicraft work should be the best approach for the needs in creative learning with CREATIONS.

5. Learning Activities & Effective Learning Environments

- Hands-on" stations
- Topic: Bionics in the water
- Different aspects of bionics directly on the compound
- Integration of the new exhibition "Ideenreich Natur"
- Learning circle:



Science topic: Bionics (Relevance to national curriculum) Class information: Year Group: 6th grade Age range: 11-14 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **printed questionnaires** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In the zoo of Nuernberg *Health and Safety implications?* - *Technology?* learning circle *Teacher support?* Yes, as a tutor learning with students
Prior pupil knowledge **Perception of technology.**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will gain an overview about different bionic areas and learn the bionics concept and its importance to know.	

Assessment **Formal learning in the zoo.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* There are some gradational learning information's for the students.	**Key Concepts and Terminology** **Science terminology:** bionics, technolgy **Arts terminology:** -
Session Objectives: learning something creative in combination with technology and science in general During this scenario, students will learn something about creative working and bionic topics.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinary* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Thinking about how inventors find their ideas	Offering some ideas about technical solutions – what might have been the model in nature.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Student find some models, e.g. sharks' skin as model for skin for planes or ships (riblet laminations) Geckos' sucker for vacuum cup	Teacher reduce their support to assistance but do not give comments	**Handicraft work about fin ray effect**

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Learning at Workstations supports learning, structured in small steps; A route card gives guide line for successful learning process, uninfluenced by the teacher.	Teachers are asked to do nothing, tutoring when needed	**Experiments with models**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students work together in small groups of four; they discuss results of their observations to fill in the route cards		**Handicrafts, creating own models**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Own results compared with original information in zoo.		

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	After the workstations students discuss their results and ideas with biologist at the zoo (that are zoo educators); they are not told about right or wrong, but discussing;	Teachers are asked to do nothing	**Additionally a robot is introduced to the students. It can sing and dance and is an example for bionics with humans as model.**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidate learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The excursion is completed with the dolphin show where students can observe the bionic model in action	In the open atmosphere of a walk through the park students are involved in open discussions with both biologists and teachers. (post-test and résumé at school complete the intervention for consolidation)	

6. Additional Information

-

7. Assessment

It's a good example for IBSE based teaching. First the problems are collected and then the guided version of IBSE is used to demonstrate the effectiveness and effort of this demonstrator. The multisensory learning with handcraft and drawing is a possible approach to bring something like that in the national school system or even in the national curriculum.

The assessment provides potential questionnaire. The Questionnaire are the SMQII, the Technology Questionnaire and the personality Questionnaire. All in all the Assessment goes through WP 6 the Validation and Evaluation effort. With these Questionnaires the effectiveness should be demonstrated.

8. Possible Extension

The normal learning in the classroom in comparison with the out-of-school learning with creative aspects could be an extension of these scenarios.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.2 Simply inGEN(E)ious! Creative modelling of DNA-structure in an outreach bio-/gene technology lab

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Julia Wank
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Version & Date:	**V1 29.03.2017**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1. Subject Domain

The module is related to the domain of Biology and Chemistry.

Simply inGEN(E)ious!
Creative modelling of DNA-structure in an outreach bio-/gene technology lab:

This intervention provides selected basic concepts around the topic of genetics and molecular biology/chemistry, especially the DNA-structure.

1.2. Type of Activity

Our educational activities are based on Creativity-enriched Inquiry Based Approaches. The specific activity is local and not a school-based activity but it consists of the collaboration between school and university and the content is according to the Bavarian syllabus. Consequently when students are visiting and working in a real university lab all implemented educational activities of the module are authentic and promote school-research center collaboration. More precise, the complete module (including various different educational activities) takes place at the outreach gene technology lab at the University of Bayreuth and is designed for 9th graders (age 14-15) at the highest stratification secondary school level ("Gymnasium") in Bavaria, Germany. One day in an outreach bio-/gene technology lab at the university shows different aspects of genetics. These aspects are presented in a gene technology module that consists of four `hands-on´ subunits supported by guided learning: one pre-lab unit, two experimental units and one modelling-unit. Thereby the modelling-unit builds a bridge between the experiments in the two experimental subunits.

1.3. Duration

Per class six hours on one day. All in all 14 classes included.

1.4. Setting (formal / informal learning)

Formal and informal setting

The setting is completely designed for learning in the lab at the university: Formal learning is located in the pre-lab and the experimental units guided by an expert because students need to be taught essential techniques of a scientist in a gene-technology lab. The modelling unit is more independent (non formal), when students create a model of DNA-structure without strict guidelines. Some parts of the module e.g. the modelling unit could also be taught at school if the required material is available.

1.5. *Effective Learning Environment*

The learning scenario takes place at the outreach gene technology lab at the University of Bayreuth. In the lab the students could learn about genetics by performing different `hands-on´ experiments and train individual skills.

- Experimentation (Science laboratories): In the pre-lab unit the students practice essential techniques of a scientist in a gene technology lab e.g., working with micropipettes and centrifuges.
- Experimentation (Science laboratories): Based on the story of a real crime the students isolate in the first experiment their own DNA out of oral mucosal cells (material level).
- Experimentation (Science laboratories): In the second experiment the students learn the procedure of a gel electrophoresis (molecular level) as one of the most important genetic lab work techniques.
- Art-based learning scenarios: are located in the lab with the handicraft work while building a model of DNA-structure. Thereby the students are linked to the discovery of DNA-structure by Watson & Crick in 1953 and can learn from their experience.
- Dialogic Space / argumentation: Communication of scientific ideas especially in the context of modelling in science is also given space during the gene technology module at the university.

2. Rational of the Activity / Educational Approach

2.1 Challenge

Models and modelling take a central place in science education, especially to stimulate the amount of new knowledge during complex themes (KMK, 2004). Specifically in genetics, that is known as a tough subject in biology class, the application of models is essential for exemplification (Rotbain et al., 2006). Indeed numerous studies (e.g., Treagust et al., 2002) have shown that students generally observe models only as visual objects (medial perception). The methodic aspect in which models serve as modifiable mediators between theory and practice rarely were analyzed in science education, although it is established scientific practice (Grünkorn et al., 2013). Marbach-Ad and Stavy (2000) found out e.g., that students have difficulties to explain macroscopic genetic phenomena by using the so called organizational micro level. As traditional science education (STEM = Science, Technology, Engineering, Maths) is often associated with negative perceptions, a lack of motivation and learning difficulties, we try to counteract these problems, thus integrating arts and encouraging creative solutions with our innovative model constructing approach. STEAM (STEM & Arts) might help to transfer enthusiasm to support individual self-efficacy as arts and creative mental abilities are required for all spheres of life and maybe especially for science.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

Models and the process of modelling are considered key elements for the work of scientists but also for citizens' participation in social discourses and in decision-making processes in their everyday life (Odenbaugh, 2005; Oh & Oh, 2011). Bridging theoretical messages and real-world experience are supposed to build a basis for scientific predictions (Gilbert et al., 1998). When pointing out that models are products of human thoughts, they also portray creativity and communication (Van Driel & Verloop, 1999). To understand and evaluate the work of scientists as well as their way of conceptualizing phenomena and to participate in scientific discourses, it is necessary to learn and know about models and their use in science (Grosslight et al., 1991).

Additionally, numerous studies recommend an inclusion of models in order to enhance teaching routines, which is why a framework for modelling and its pedagogical contribution is needed. Following Justi (2009) we consider the four main stages of the `Model of Modelling´ (Justi & Gilbert, 2002): collecting information about the entity that is being modelled (1), producing a mental model (2), expressing that model in an adequate representation form (3), testing and evaluating its scope and limitations (4). Consequently, students gain from the implemented activities specific skills: When observing our participants, we strongly agree that the artistic compound in working with various handcrafting materials in biology class positively attracts learners' attention and supports motivation during model construction. One reason might be that students could act more creatively and without any limitations in presenting the given information than in traditional model-supported approaches, in which the medial perception (e.g. model viewing) is typically favored. Furthermore, giving extra space for communicating scientific ideas supports students' reasoning skills and enforces pupils to stand up and speak for their opinions. This is important because social participation and democratic discussions about upcoming genetic challenges and inventions require a scientific literate public.

The CREATIONS framework finally gives the framework of this learning out of school in a gene technology lab at the university.

3. Learning Objectives

3.1 Domain specific objectives

a) The main aim

The core element of creativity has made science one of the major cultural achievements, specifically in the context of modeling (Van Driel & Verloop, 1999). Consequently, the main aim of the demonstrator is to improve students' creative thinking in science via inquiry-based learning and creative investigations and negotiations. Creativity is defined as a combination of talent, knowledge, ability, intrinsic motivation, and personal traits, additionally influenced by environmental impacts. With this the influence of Creativity on modelling will be checked. Thereby the reliability of an existing Creativity Questionnaire (Miller & Dumford, 2014) should be tested.

b) Domain specific objectives

Suitable approaches for outreach learning are often inquiry-based; learners may propose ideas, explain observations, and verify hypotheses. Inquiry-based learning scenarios tend to emphasize critical, independent and problem-based thinking; related challenges are often connected to students' everyday experience (Sotiriou et al., 2017). Our participants pass the Inquiry Process (described in detail *2.2.* and 5.) while visiting the outreach gene technology lab at the University. Herein, we favor a situation in which students should become more independent in reasoning and exploring, reaching a deeper understanding of the learning content and transferring learning information in other contexts. Thereby, a more structured version of inquiry may allow learners for example to focus on interpretation of results and on linking experiment with theory.

Out-of-school settings offer such authentic and student-centered learning environments. Specifically outreach labs may allow learners to provide authenticity and to feel like real scientists: While performing the gene technology module in the lab students develop searching skills with the intent to solve realistic problems and learn to give scientific explanations. They get access to scientific thinking and experience scientific concepts in a real lab situation.

c) Additional aims:

Another essential question of this project concerns how far the independent modelling of the DNA-structure supports short-term and middle-term increase of knowledge and students´ understanding of the role of scientific models (Treagust et al., 2002). Thereby students may link their school knowledge to scientific theory and everyday life.

Is there an influence of cognitive load (CL) during the learning units? Furthermore the effect of the variables creativity (Miller & Dumford, 2014) and science motivation (Glynn et al., 2009) will be investigated.

3.2 General skills objectives

Genetics and DNA-structure supposed to be taught in different ways. Learning in an outreach bio-/gene-technology lab is not mediated as in school. There is a new way teaching students and looking for students' problems and alternative perceptions. The issue of this skill is `learning by doing´. For this reason handicraft should be a meaningful topic in the context of modelling. The students should work with the hands not only

with the eyes. With the scientific support to their cases students develop and increase their research skills. Another important skill that is trained in the gene technology module is students-collaboration. This means that they learn to work together outside the classroom and collaborate to a common goal. This spirit of teamwork means that students learn to fully support their hypotheses with strong scientific evidence, they also listen to each other and finally they come to a common decision all together. Concluding that our model constructing approach gives a working strategy for a successful STEAM approach, in supporting students´ research and modelling skills as well as their abilities for constructive dialogues.

4. Demonstrator characteristics and Needs of Students

4.1 *Aim of the demonstrator*

Research-based learning (Inquiry Based Science Education) plays a major role in science education (Bogner & Sotiriou, 2011). A main principle of the demonstrator was to provide meaningful activities in authentic environments, thus supporting students' engagement to the complex and abstract field of genetics. Therefore, a gene technology module at the outreach bio-/gene technology lab at the University of Bayreuth around the theme of DNA-structure was established. The learning content is designed for 9th graders (age 14-15) at the highest stratification secondary school level (`Gymnasium´) in Bavaria, Germany and follows the Bavarian syllabus. The intervention provides selected contents around the topic of DNA. Students gain an overview about different work techniques in a bio-/gene technology lab and learn the structure of DNA and its importance to know.

According to the *IBSE* approach the students are confronted with some *questions* during the gene technology module: They isolated first their own DNA as a white substance in a test tube, but how is it organized on molecular level? How can this molecule store the whole genetic information? As an *evidence* to acquire their knowledge about the DNA-structure students get now further information while reading a text about the scientist Francis Crick. After *analyzing* the text students should do some handicraft work in the modelling-subunit. They get no detailed guidelines so students have to form their models in a creative and independent way. With these skills they should learn more about modelling in science. So students could change their models while working on them. They could also compare and discuss their model with others and with the model from Watson & Crick (according to the essential features of IBSE: *Explain*, *Connect* and *Communicate*). In addition to that students should draw and describe their model at the end of the subunit to save the information with multisensory learning (*Reflect*). Through such learning activities the creative aspects are trained in different ways.

Additionally, hands-on modelling presents a complex strategy to reach understanding that offers multiple ways for learning and understanding routes to historical discoveries. In consequence, we combine in our outreach module experimentation with creative model work in order to visualize molecular and otherwise invisible contents of DNA-structure. This means that students work in the scientific lab like real researchers. By creating a model of DNA-structure, they learn by doing scientific work. When constructing their models they have to transfer each characteristic of theoretical concept to a new handicraft, working on multiple semiotic systems. The students have to transfer what they learned theoretically to another cognitive system and this transference helps them to connect the key features of each notion (DNA-structure).

4.2 *Student needs addressed*

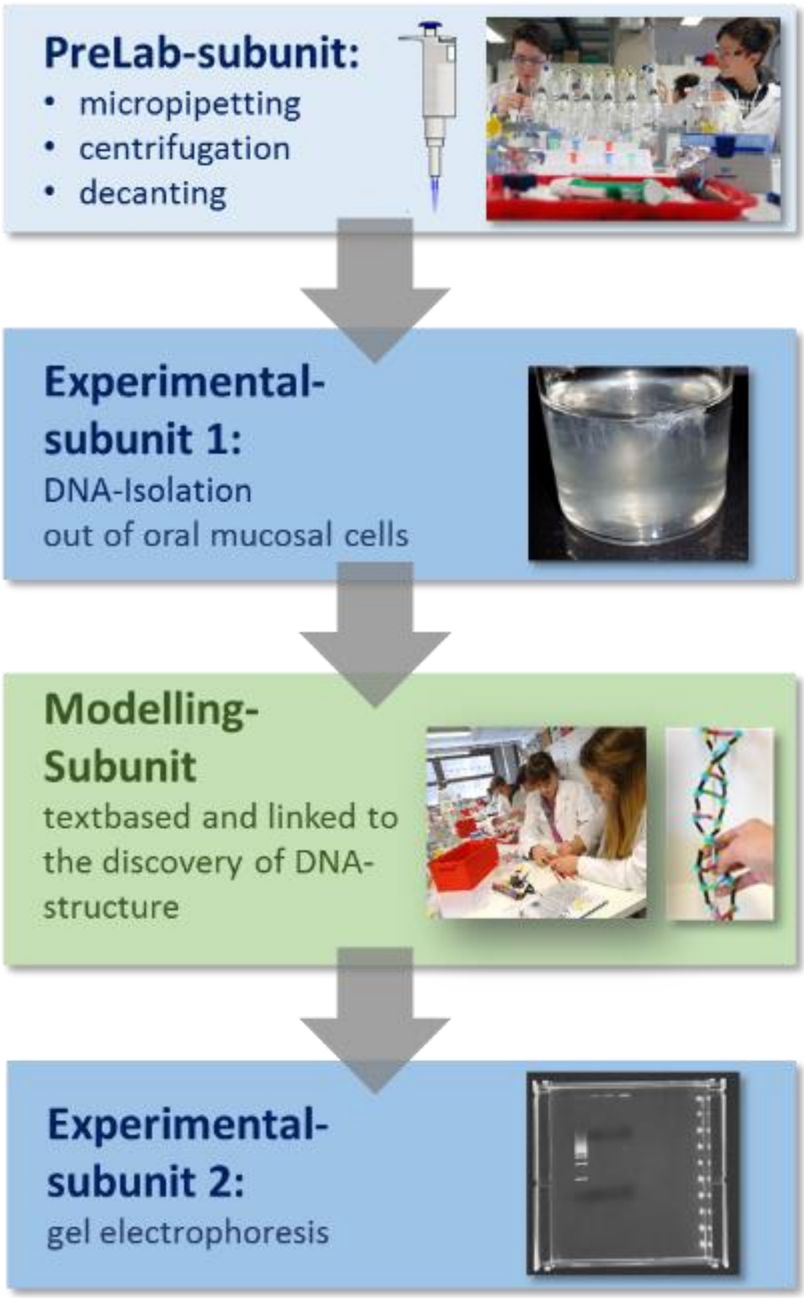
A main principle of the demonstrator is to strengthen students' engagement to meaningful activities in authentic environments. This means that students work in the scientific lab as real researchers. By creating a DNA model and structure, they learn by doing scientific work. On this stage of constructing a DNA model they have to combine each characteristic of theoretical concept to a new handicraft, working on multiple semiotic systems. The students have to transfer what they learned theoretically to another cognitive system and this transference helps them to connect the key features of each notion (DNA structure).

Therefore students should bring some skills in the gene technology module: They should have perceptions about essential biological and chemical concepts, interest in modelling in science and social aspects of

genetics. This together with handicraft work should be the best approach for the needs in creative learning with CREATIONS.

5. Learning Activities & Effective Learning Environments

- Topic: Creative modelling of DNA-structure
- Hands-on `experiments´
- Modelling subunit
- Approaching different levels of understanding DNA-structure: students learn to explain macroscopic genetic phenomena by using the so called organizational micro level
- <u>The gene technology module:</u>



CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: DNA and genetics (Relevance to national curriculum) Class information Year Group: 9th grade Age range: 13-15 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **printed questionnaires, materialbox for modelling, laboratory equipment, chemicals for the experiments, workbook with instructions for the experiments** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* in the outreach gene technology lab at the University of Bayreuth *Health and Safety implications?* safety googles and laboratory coat *Technology?* module with guided and independent phases *Teacher support?* Yes, as a tutor learning with students
Prior pupil knowledge **Perception about essential biological and chemical concepts, interest in modelling in science and social aspects of genetics, writing laboratory minutes** Phase 1: PreLab-subunit ('Be prepared! How to work like a gene-technology scientist'): basic experimentation skills and basic lab vocabulary (e.g. pipettes, beaker, testing tube) Phase 2: Experimental-subunit 1 ('Spin your DNA! The material charcter of DNA'): basic experimentation skills (pipetting), documenting experimental work Phase 3: Modelling-subunit: basic handcrafting skills, imagination of invisible phenomena Phase 4: Experimental-subunit 2 ('Visualize the invisible – Agarose gel electrophoresis'): basic experimentation skills, documenting experimental work	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will gain an overview about selected basic concepts around the topic of genetics, especially the DNA-structure.	

PreLab-subunit: Students get an introduction to the lab, to safety rules and to the most important equipment for the experiments in the module, e.g. centrifuges and micropipettes. After of a theoretical part they do some practical exercises before starting with the main activity.

Experimental-subunit 1: Based on the story of a real crime Students have to isolate their own DNA out of oral mucosal-cells; they get a short introduction by a scientist and a specific workbook and after that they perform the experiment together with a classmate; aim of this phase is to observe DNA as a substance (material level).

Modelling-subunit: Students get a text linked to the discovery of DNA-structure by Watson & Crick in 1953. After reading the text by themselves and discussing its content with a neighbour they do some handicraft work while building a model of DNA-structure in partnership with a classmate. Communication of scientific ideas especially in the context of modelling in science is also given space.

Experimental-subunit 2: In the second experiment the students learn the procedure of a gel electrophoresis (molecular level) as one of the most important genetic lab work techniques. They work together in small groups along the instructions in the workbook shortly after a theoretic introduction to the experiment was given by a scientist.

Assessment	**Differentiation**	**Key Concepts and Terminology**
A pre-test (knowledge, CPAC, understanding of scientific Models) **is given before students start with learning activities to evaluate prior knowledge. After passing the final stage they complete a post-test** (knowledge, SMQ II, understanding of scientific Models)**.**	*How can the activities be adapted to the needs of individual pupils?* The students can choose material and content of their DNA-model independently.	**Science terminology:** genetics, representing DNA-structure, modelling **Arts terminology:** modelling, drawing, handicrafts **Modelling terminology:** model based learning, model building, modelling space, modelling primitives, formalisms, scientific objects and real objects, object entities etc.

Session Objectives:

During this scenario (clarifying a crime), students will learn something about creative thinking as well as selected basic concepts about genetics specifically about DNA-structure.

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	pre-test before participating in the gene technology teaching-unit Thinking about how the police/forensic technicians could clarify a crime	Offering the case of a real crime scene documented in the newspaper	-
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Reading a text about the discovery of DNA-structure by Watson & Crick	Teachers reduce their support	-

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Discussing the text with an immediate neighbor and answering questions on the text together	Teachers reduce their support, tutoring when needed	**-**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Building a DNA-model independently by using the answered questions from Phase 3 and a special materialbox	Teachers reduce their support and give no comments	**Handicraft: Creating own models of DNA-structure. Drawing: Students draw and inscribe their DNA-models**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Comparing their own results of modelling with the original model of Watson & Crick (as picture)		**-**

	their evidence and explanations in relation to the original question.			
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	After modelling students discuss their results and ideas with a scientist at the gene technology lab; they are not told about right or wrong, but discussing the different models actively	Teachers follow the discussion but give no comments	-
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The module is completed by finding an explanation to the results of the gel electrophoresis (experimental-subunit 2) by using the DNA-model in action (animation); a post-test is completed at the end of the day (see below)	Teachers pass a retention-test six weeks later and a résumé at school to complete the intervention for consolidation	-

6. Additional Information

- **Materialbox for modelling (Example):**

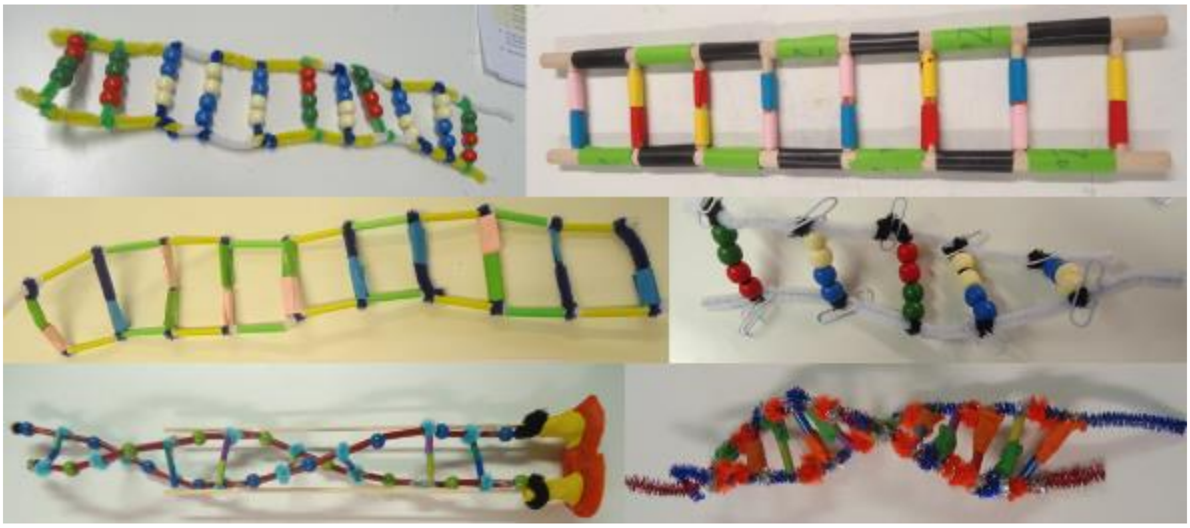
- **Homepage of the New York Times (Department Science):**

  "My Dear Michael, We've Discovered DNA"

  Writing to his son, Michael, Francis Crick tells of a "most important discovery."
  http://www.nytimes.com/interactive/2013/02/26/science/crick-letter-on-dna-discovery.html?_r=0

- **Interactive 3D DNA molecule-viewer**
  http://www.chemie-interaktiv.net/jmol_viewer_Ia_dna.htm

- **Impression of possible DNA-models:**



7. Assessment

This module is a good example for IBSE based teaching especially in case of the modelling-subunit. First a problem is collected and then the guided version of IBSE is used to demonstrate the effectiveness and effort of this demonstrator. The multisensory learning with handicraft (modelling) and drawing is a possible approach to introduce this in the national school system or even in the curriculum.

The evaluation provides potential questionnaires that should demonstrate the effectiveness: These are a specific knowledge-test, the SMQ II (Glynn et al, 2009), the CPAC Creativity Test (short version; Miller & Dumford, 2014) and students' understanding of the role of scientific models (Treagust et al., 2002). These tests could be separated to pre-evaluation before participating in our gene technology teaching-unit (knowledge, CPAC Creativity Test & students' understanding of the role of scientific models) and post-evaluation directly after the teaching-unit (knowledge, SMQII & students' understanding of the role of scientific models).

8. Possible Extension

Normal learning in the classroom in context of genetics could be compared with the out-of-school learning with creative aspects. There could also be a comparison between independent creative modelling face to face by working with simple school used models. In addition the topic of negotiation and modelling may be differ and expanded on other topics besides genetics. Besides this activity may be held as a small scale local activity, for example different schools or even research centers apart from labs at the university could also participate.

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D3.2.3 UBT Archaeopteryx and bird flight

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Alexandra Buck (UBT)
Code:	D 3.2.3	**Contributors/ Organization:**	Sofoklis Sotiriou (EA)
Version & Date:	V4 2018-05-14	**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.1. Subject Domain

Archaeopteryx and bird flight- why do birds fly?

The implementation provides selected bases around the theme of Archaeopteryx and the natural phenomena of how birds fly. Thus, the topic treated with the subject domains of biology and physics.

IBSE learning and CLIL in combination with arts in science teaching

1.2 Type of Activity

Educational Activity based on Creativity-enriched Inquiry Based Approaches (school based):

An Inquiry-based-CLIL learning program (content and language integrated learning) in Greek and German language is implemented to enhance student's motivation in science classroom for 6th.grade at school.

At their regular class room, seven workstations were provided, structured in an interactive learning circle, which includes multimedia tools with modern technology for eLearning as well as hands-on experiences with natural feathers, the Archaeopteryx fossil replica and padded bird species for demonstration. Also a collaborative handicraft artwork with fossils is included.

1.3 Duration

The time for the implementation program was four school hours per class. Overall, seven 6th grade classes were included. School hours were split into two parts 2x2 school hours to integrate the activity in regular school schedule during mornings and afternoons. The implementation ran over 2 ½ weeks at EA from 01.02. - 17.02.2017.

1.4 Setting (formal / informal learning)

Formal learning is applied in school as classroom activity. Students participated in learning program with teachers integrated only as guides for help in organizational questions. Students worked informal in workgroups together and solved tasks at table workstations independently.

1.5 Effective Learning Environment

The effective learning environment was located at the primary school Ellinogermaniki Agogi, Pallini Athens (EA) in cooperation with CREATIONS EU-partners from EA. The school provided a classroom for the learning station environment. The stations were set up on tables, so students could learn about Archaeopteryx in groups and train individual skills. Learning at workstations supports effective, interactive learning which are structured in small steps.

Focusing on school classroom for the project implementation will give a diversity of children from all backgrounds the chance to participate in the program. Children from all levels and different abilities and

interests in natural science and greek-german language class are able to work together and learn a different approach in science education, which gives them space to discover, experiment, engage and be creative. School classroom is an effective learning environment because it socially includes a diversity of children from those, which are highly skilled, as well as handicapped, those who favor science subjects and the opposite. In school classroom gender equality is respected and especially girls are encouraged to learn and engage in natural sciences program which is usually more a boys domain and more easy for them to connect with. So in classroom children from various interest groups are challenged in natural science education.

Learning topics are adequate to school curriculum of 6th grades in biology, which include the theory of evolution, identifying vertebrate features and learning about birds and their ecological environments.

- Dialogic Space / argumentation, Experimentation with model:
  Students learn about Archaeopteryx and the evolution of birds directly on the fossil replica of Archaeopteryx, which is provided in collaboration with the Juramuseum in Eichstätt. At "hands-on" stations, they can touch and experience the fossil skeleton and learn about its distinct reptile and bird features.
- Simulations; Experimentation; Arts:
  Simulations of the body and wings of birds and airplanes are shown in the learning scenarios, which should be visualizing the physical phenomenon of the uplift in the air. Inquiry based experiments should be brought in classroom to practically experiment with.
- Arts-based:
  Art based learning scenarios are located in the classroom with the handicraft work of forming a fossil art picture with clay and natural elements (feather, shells) collaboratively to demonstrate the process and different steps of fossilisation.
- Simulations:
  Use of modern Multimedia tools (laptops, short movies about bird flight) as well as fossils, padded bird expositions for hands on are handy and practical for use in classroom.
- Dialogic Space / argumentation:
  Communication of scientific ideas is given during the learning program to exchange arguments, share ideas and find solutions collaboratively in the work process. The students can talk in groups while solving tasks, learn from their individual experience in science, and communicate about problems and the fossil/bird flight topics, which are linked with that.

2. Rational of the Activity / Educational Approach

2.1 Challenge

Alternative perceptions about evolution (biology) and bird-flight (physics) often prevent learning. Complex topics cause cognitive overload. This can result in an negative image of scientific topics causing demotivation and low learning effects.

Another topic of this demonstrator was learning languages and promoting language-learning motivation. Learning complex languages might decrease learning motivation. A negative self-efficacy might enable the development of a fluid spoken foreign language.

2.2 Added Value

Alternative perceptions might prevent learning or lead to mixed alternative models. For a conceptual change, a conscious perception of one's own misunderstandings enables learning at all. Therefore, hands-on learning and experiments provide a self-regulated learning environment. The Arts-aspect provides the experience of both freedom of choice and freedom of criticism and thus, opens the minds.

Students hardly have any experience about fossils (e.g. archaeopteryx), evolution, and bird flight topics before. With this demonstrator, students will find out by thinking about different everyday examples which they know and can connect with.

The composition of the learning program is interdisciplinary and contains topics and tasks of different science disciplines: Biology, Palaeontology and Physics. Additionally all four-competence fields of science learning are promoted: expert knowledge, interdisciplinary skills, gaining awareness, communication and evaluation. Students will create handicraft and work collaboratively on different stations in the classroom. They need to draft questions, execute them in experiments and save the information/answer through protocol writing.

To promote motivation to learn languages, the workstations were offered bilingual (first language: Greek, foreign language: German). As the focus was on the science education the usage of the foreign language

A negative self-efficacy might enable the development of a fluid spoken foreign language.

Furthermore, language-learning motivation might be promoted when students have the experience of self-efficacy and success with their additional skills. To reduce cognitive overload and support language learning both Greek and German info boards were provided. Thus, students can learn instructions and scientific correct information with both languages and improve their language skills based on the language level which they prefer to read or which they are able to understand. Always considering every child's individual needs.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the demonstrator is to improve students' creative thinking skills in science via inquiry-based and creative investigations and negotiations. Creativity is an important ability for both problem solving and scientific thinking. The domain specific objectives are inquiry processes, experiencing scientific concepts while developing the scientific thinking ability. Additionally, cognitive load was reduced by concurrent sophisticated learning environment. Well prepared working stations provide possibility for students to work learning matter out on their own by developing searching skills. With experiments, students can get positive try and error experience, a basis for creative and scientific thinking.

3.2 General skills objectives

Main goal of the demonstrator is collaboration with high grade of freedom of choice and try & error learning to promote creative thinking. The working-stations deal students-centred with teachers in the role of tutors. Students cannot make "mistakes", but have the chance of problem solving in groups, exchanging ideas, discovering natural objects and conducting experiments about nature phenomena.

The students cooperate in small groups of three to four in a high grade of self-regulation and freedom of choice. Thus, they work with self-responsibility for their results and present their peer group. Therefore, they need to use their dialog skills to both discuss their results in the peer group and in the class.

Included in the implementation quantitative tests will measure creativity and motivation potential of students in order to draw conclusions for optimizing teaching methods.

1. Is there an increase of knowledge due to the method of inquiry based science intervention (IBSE)? Is there an effect of state emotions and science motivation on the increase of knowledge? (Glynn et al., 2011), (Randler, 2011)?
2. Is the motivation of children in science associated with the creative process?
3. The students engagement of working socially in groups as well as the connectedness with nature will be measured by tests from every student individually with respect to the learning program (Student Engagement Kong, Wong, Lam 2003), (INS, Schulz 2002)
4. Is there an influence of cognitive load (CL) during the learning unit?
5. Is there an influence of certain personality traits? (cognitive ad-hoc test Paas et al., 1994)

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Inspiring science learning plays a major role in science education (Sotiriou, Bogner 2011). Therefore research-based learning activity (Inquiry Based Science Education) is chosen as favourite method for designing the learning program on Archaeopteryx and bird flight. Encouraging deeper learning in connection with science and arts will be given special emphasize (the Arts in Science education) in order to enhance students motivation.

Students will learn general skills that can hardly be measured but perceived by teachers and employer.

The main aim of the demonstrator is to improve students' creative thinking skills in science via inquiry-based and creative investigations. Well prepared working stations provide possibility for students to work learning matter out on their own by developing searching skills. At workstations there are no answers given, but questions occur.

Implementation of art distracts from the scientific content, diverting students' everyday focus to right and wrong as the main criteria for performance assessment. Students need to experiment with the chance to get positive try and error experience, a basis for creative and scientific thinking. To find solutions students play around with brainteasers, e.g. the glider models.

To inter-connect knowledge from different workstations dialog and cooperation of the team is needed. They work with self-responsibility for their results and present their peer group. Therefore, they need to use their dialog skills to both discuss their results in the peer group and in the class. This spirit of teamwork means that students learn to fully support their hypotheses with strong scientific evidence, they also listen to each other and finally they come to a common decision all together.

The individual stations deal with different disciplines, so that the main topic (bird flight) is considered from various perspectives. Thus, relationships become obvious and knowledge stable. As the knowledge of different workstations will help at the other stations students might gain an joyful experience of networked thinking. We hope to arouse the joy of scientific tinkering and science motivation.

Students gain an overview about different areas in physics, biology and palaeontology, concepts of evolution; learn the relation between morphology, physical body composition and the livelihood of birds in different environments. In addition to the handling with multimedia and technology, Students also learn to experiment with different nature phenomena such as uplift, gravitation and gliding with thermal uplift, which they can connect with physics in everyday life.

4.2 Students needs addressed

5. Learning Activities & Effective Learning Environments

- The learning topics of the program "Archaeopteryx and bird flight" is structured in three modules:
  1. Arts with fossils in science
  2. Archaeopteryx - missing link of evolution,
  3. How do birds fly? Experiments with different types of bird flight
- As teaching method, "inquiry-based science education" is applied, through questioning, experimenting, discussing, protocol writing, and evaluation. Each student will answer questions and draws notes in his/her own protocol booklet. Fossils and padded bird species are provided as demonstrational real natural objects.
- As educational tools, hands-on stations are used in various workstations with the fossil replica and multimedia is used with integrated eLearning and short clip movie about bird flight as well as airplane simulation to show uplift. Another tool is the observation of birds in their natural environments (mountain, rainforest) on wildlife movie clips, learning their flight behavior and answering questions in protocol booklet. As third tool creative handicraft with paper flights and a handmade collaborative fossil artwork are integrated too.
- Learning circle with 7 work stations (see attached below next page)

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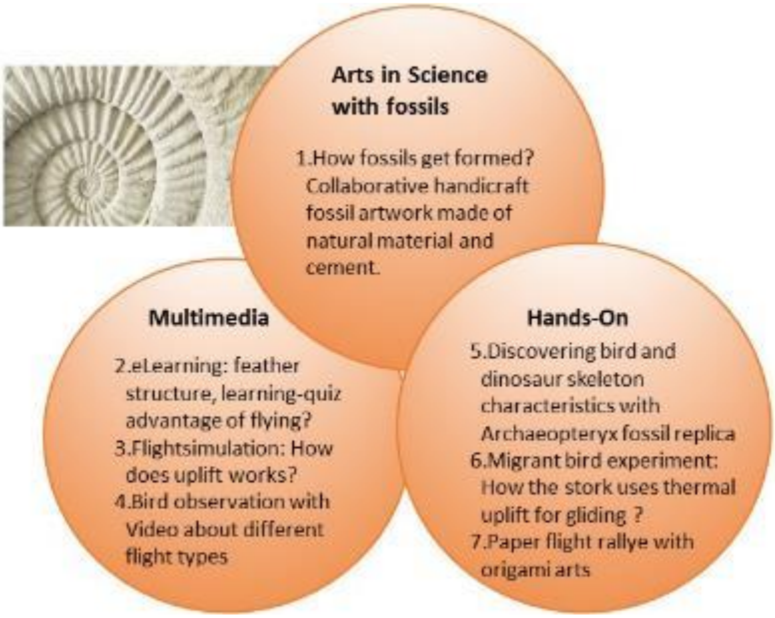

<table>
<tr>
<td colspan="3">Science topic:
Archaeopteryx and bird flight (Relevance to 6th grade curriculum)
Class information: Year Group: 6th grade
Age range: 11-13
Sex: both
Pupil Ability: The scenario allows space for students of various abilities to participate</td>
<td colspan="3">Materials and Resources
Protocol booklet, printed questionnaires, Archaeopteryx fossil replica (in collaboration with Museum), technical tools (laptops).
Where will the learning take place?
The learning takes place at school in classroom (Ellinogermaniki Agogi EA, Pallini Athens).
Health and Safety implications? Not required
Technology?
A CLIL and multimedia eLearning and hands-on circle based on table workstations
Teacher support?
Teachers are in the passive role of a tutor</td>
</tr>
<tr>
<td colspan="6">Prior pupil knowledge
Perception of ancient birds and how do birds fly from everyday life observations</td>
</tr>
<tr>
<td colspan="6">Individual session project objectives
Students will gain an overview about different topics on Archaeopteryx – bird evolution and learn natural phenomena about how do birds fly and its importance to know.</td>
</tr>
<tr>
<td colspan="2">Assessment
Informal learning in classroom at school</td>
<td colspan="2">Differentiation
The learning information is given in info- boards for students with knowledge and language level of 6th grade (greek and german) so students can adapt to it.</td>
<td colspan="2">Key Concepts and Science Terminology
IBSE learning with CLIL and arts in science education (eLearning and hands-on) Terminology: Fossilisation, theory of bird evolution, dinosaurs, gravitation, thermal uplift, gliding, bird</td>
</tr>
</table>

		species, ecosystem, artwork, origami,
Session Objectives: **learning creative artwork, experimenting on natural phenomena of bird flight in combination with archaeopteryx fossil and eLearning tools. Learning science in different languages through CLIL enhances motivation and students interest in science.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students are given scientifically oriented questions in the instruction booklet to investigate questions students to be creative learners and get into the role of science communicators in an open and structured approach to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinary* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students will get the role of science researchers and investigate questions and answers to find out more about the life of Archaeopteryx: Was it able to fly? Which body features make flying possible? How are fossils made? What is thermal uplift and how is the stork using it to travel to Africa?	Generally, teachers stay in background to let children be in focus and find out answering research questions on their own with the help of instructional booklets. This will give children more freedom and space to think and find solutions. Teachers offer help in case if needed or by organizational, technical questions.	How are fossils made? Is demonstrated by making a collaboration handicraft fossil artwork using natural materials (feathers, shells and cement) to experiment the process of fossilisation. How do albatross glide? Is answered by forming a paper flight and tried out by the paper rallye.
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to	Students discover the distinct features of birds and dinosaurs on the skeleton of Archaeopteryx original replica. <u>They will witness the evidence of the origin of birds</u> and the evolutionary relation between vertebrate	Teachers stay in the background and guide only if needed to let space and creative thinking to students. Instructional guide and materials on skeleton features is provided on workstations.	Drafting the skeleton of Archaeopteryx with colours to save the information's and learning items in the protocol booklet.

	generate, question and discuss evidence.	species on <u>the "missing link" of Darwin's evolution theory.</u>		Fossils are provided as demonstrational real natural objects
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students make observations about the phenomena of thermal uplift and conduct small experiments to analyze the evidence of uplifting. Also analyzing types of bird flight behavior in videos tools.	For successful learning process, teachers give tutoring only when needed. Easy language instructional cardboards will guide students through experimental set up.	Experiments with feathers, candle and science-to-go airplane /bird flight simulation
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students work together in small groups of four. They discuss the results of their observations and make notes in their protocol booklet.		Handicrafts of paper flight, Studying body shape of padded bird species
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect their explanations and ideas with scientific knowledge and improve their answers. They compare with original information on cardboards.	Didactical information on cardboards give guided theoretical background information (both languages identical in Greek and German for convenience)	

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Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	After the workstations, students discuss their results and ideas among their group members and note the learned topics in protocol booklet, if necessary make corrections.	(Biologist) teacher assisting as tutor may help at this step and discuss with children.	Studying birds and fossils hands on will make learned theoretical knowledge easy transferable and understandable with real natural objects
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidate learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The circle is completed with the paper flight rallye and opening handicraft fossil artwork of where students can reflect the originating of fossils	Post-test and résumé at school as well as feedback questionnaires complete the intervention for consolidation.	

6. Additional Information

In framework of CREATIONS (developing and engaging science classroom) this best practise demonstrator contributes for the international science-school network and eLearning platform of CREATIONS which provides teaching material and information for teachers and researchers.

The study is part of the EU project collaboration and engages to strengthen students and teachers in MINT-subjects and natural science education. This project is supported by the EA research team, primary school EA and University Bayreuth.

7. Assessment

This best practise demonstrator is a new innovative example for IBSE learning and CLIL in combination with arts in science teaching. First, the problems are collected and then the guided version of IBSE will demonstrate the effectiveness and effort of this implementation. The multisensory learning with multimedia eLearning as well as hands on stations with use of natural objects (Archaeopteryx replica, birds) is a possible approach to bring some interactive, informal learning based on workstations in the national school system or even integrate it in the school curriculum.

For evaluation of the implementation, questionnaires and feedback for students are provided. The Questionnaires used for scientific research are the SMQII (science motivation questionnaire) by CREATIONS, CPAC (creative process associated with creativity) (Miller, Dumford, 2014), state emotions (Randler, 2011), Student engagement (Kong, Wong Lam, 2003), Intrinsic attitude towards nature (Schulz, 2002). Help-seeking behaviour (Morris 2008), cognitive load (Paas, 1994). All in all the Assessment goes through (WP 6) of the Validation and Evaluation effort. With these Questionnaires, among several research questions the effectiveness of IBSE learning and the student's motivation and creativity in correlation with their attitude towards natural science learning and student engagement will be measured.

In science teaching and didactics research, the focus is on studying the school reality with the aim of optimizing science teaching. Evaluating the impact of the implementation can help to improve and find new, innovative teaching methods.

8. Possible Extension

The implementation can be conducted by any kind of teachers once the material and facility is provided in any school scenario. Material which is basically info cardboards, laptops, and demonstrational natural objects for fossil artwork and the Archaeopteryx fossil can be multiplied easily and be possibly integrated annually in school curriculum.

Another possible extension of these interactive and informal learning in school scenario could be the integration of the program in summer school events, summer school camps during school holidays or during special project days at school.

Furthermore some topics in the program can be extended such as raising environmental awareness for the protection of birds by showing card and movie material about birds in natural ecosystems which are located close to the students homeland area. For example Delta Ebpoy coastal wetland area which is home to most European water birds like Pelika and Flamingos which are discussed in teaching material already. And Dadia Lefkimi Soufli National park which is one of the last protected resorts for the great European vultures and eagle population in Greece. Children can learn about species in their natural environment and especially connect directly with their local homeland and bird species, which some might have seen before and learn the fascination and protecting them.

Another topic is the integration of ancient Greek mythology of Icarus and Daedalus in connection with the everlasting human dream to fly and historic human inventions of airplanes and constructing flight objects as ideas being induced on the fascination of birds.

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D3.2.4 FutureForest – combining creativity with biodiversity education

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:** Jennifer Schneiderhan
Code:	D 3.2.4	**Contributors:**
Version & Date:	V1, 16.03.2018	**Approved by: NKUA**

1. Introduction / Demonstrator Identity

FutureForest is a learning module designed for biodiversity education by the department of biology education of the University of Bayreuth.

2.1 Subject Domain

The specific subject domain is biodiversity, which is an important part of education for sustainable development, environmental learning and biology education.

4.2 Type of Activity

Our learning module contains educational activities based on creativity-enriched and inquiry based approaches. In order to expose students to learner-centered, authentic and cooperative learning, a learning circle was the method of our choice. Based on an introductory phase, students, who work together in small groups of four, go through four different learning stations. All necessary material (e.g. info texts) is displayed at these stations and a workbook provides the tasks to be solved. In such a learner-centered approach, the teacher takes on the role of an advisor rather than a mediator of knowledge. They answer student's questions but do not further intervene in the learning process.

A stated above, the learning activities of our module are based on the *Inquiry Based Science Education (IBSE)* approach. Each station is concerned with a research question or problem to be solved in the course of the assignments. In addition, the module's activities incorporate several CREATIONS features, e.g. *dialogue*, *interdisciplinarity*, *individual, collaborative and communal activities for change* or *risk, immersion and play.* Further details concerning the tasks will be explained in chapter 5. "Learning Activities & Effective Learning Environments".

Additionally, *FutureForest* aligns with the *Responsible Research and Innovation (RRI)* approach, because it incorporates educational activities that promote school-research center collaboration. In cooperation with the *Bavarian State Collection of Zoology* in Munich*,* we have integrated a citizen science project into a classroom setting. The Munich scientists are part of *the International Barcode of Life Project (iBOL)*, the largest biodiversity genomics initiative so far. Within our module students collect forest soil samples. These samples are DNA-barcoded by real scientists, i.e. there is a direct collaboration between the researchers at the *Bavarian State Collection of Zoology* in Munich and the participating students at the schools. The students have the opportunity to actively take part in real scientific research, because the student-gathered and generated data is uploaded to the international online barcoding database, the so-called *Barcode of Life Data System (BOLD)*.

The activity is a local activity but the data gathered by students contributes to national and international barcoding projects and research.

4.3 Duration

The completion of the whole module takes 180 minutes. To incorporate specific activities into the framework of a lesson period of approx. 45 minutes (depending on the country-specific framework), it may also be

possible to select or exclude individual phases of the learning circle, which take approximately 30 minutes each, plus an individual introduction and revision phase.

4.4 Setting (formal / informal learning)

We conceived *FutureForest* for formal learning in a classroom setting. All activities are student-centered, while the teacher takes on the role of an advisor only.

4.5 Effective Learning Environment

The learning module takes places in a classroom setting and integrates a citizen science project. At one learning station students work with a simulation. Additionally, the students do a role-play, where they have to think creatively, share their ideas, change perspectives and think together to find a possible solution. This is called 'exploratory talk' and the effective learning environment is dialogic space or argumentation (see e.g. Wegerif and Mercer, 1997).

It is also possible to organise a real or virtual visit to research centres or (see chapter 8 "Possible Extensions" for further description). You should choose at least one of the following Effective Learning Environments according to the framework (If you need more details about Effective Learning Environments, you can see D.2.3.):

- Communities of practice
- Simulations
- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centers (virtual/physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

Biodiversity conservation is one of the major challenges of our time (Hoban and Vernesi 2012). Since biodiversity is threatened on a global scale, its heritage for future generations is at risk (Joppa et al. 2016). Recent reports about the decline of insect diversity point to the extent of this crisis (Hallmann et al. 2017). Reducing biodiversity loss and the achieving sustainability goals, requires an understanding about the main causes, focusing on anthropogenic activities and interferences (Isbell et al. 2013). Therefore, biodiversity education may function as a key element of education for sustainable development, because environmental challenges require a scientific literate public. The pedagogical challenge herein is, that several studies report about an increase in students' alienation from nature and a lack of students' scientific knowledge on nature in general and species identification skills (see e.g. Bebbington 2005, Potvin and Hasni 2014). In order to increase students' science motivation concerning the environmental problem of biodiversity loss, we incorporated the IBSE and RRI approach in our learning module to enable students not only to learn about but also to contribute to real-life environmental research.

2.2 Added Value

Our module exposes students to real-world problems and major global, societal challenges. By following the IBSE approach, we want students to think critically about nature utilization and protection. We want students to be able to generate applicable knowledge instead of mere factual knowledge. Only if they are able to apply their knowledge to real-world matters, they will become responsible members of our society. In *FutureForest* students are confronted with several questions and problems concerning biodiversity loss. For example, they read a future scenario of a forest threatened by climate change and conventional forestry. They get to know helpful strategies for the conservation of nature and especially biodiversity.

The module follows several features of the CREATIONS framework, e.g. the IBSE approach, RRI aspects. For example, we integrated a citizen science project. This offers students the opportunity to take part in real science research. Students collect forest soil samples, which will be DNA-barcoded by scientists. During the module, they get to know, how their samples contribute to a global DNA-Barcoding-Project, which wants to assess every species of our planet.

3. Learning Objectives

3.1 Domain specific objectives

The domain specific objectives are to enable biodiversity education, to integrate citizen science into a classroom setting and to combine environmental education with IBSE and creative learning. Our demonstrator is learner-centered and follows the approach of collaborative learning with the aim of fostering collaborative creative thinking within a dialogic space. Students need to be able to think together and change their perspectives to find common solutions and strike compromises. This is a core requirement to enable them to become responsible citizens. Only if we foster our future generations to feel responsible for our planet and for their environmental behavior and to counter problems in a creative, collaborative manner, we are able to solve or at least ease the major environmental problems of our time, e.g. biodiversity loss. We, therefore, think that the combination of Biodiversity education with creative thinking skills should be a key element of environmental education.

3.2 General skills objectives

Our learning module fosters different general skills. On the one hand, the students train professional working techniques and on the other hand, they practice social skills. In the following, we represent the skills exemplarily:

- Professional working methods and techniques:
  - using a microscope or binocular to examine forest soil organisms
  - using a identification key to morphologically identify forest soil animals
  - compare the characteristic of different soil organisms

- Social skills:
  - communicate and discuss issues with group members
  - accept different points of view
  - strike compromises or common solutions
  - ability to change perspectives

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is, to enable environmental learning trough the CREATIONS approach. Our module, and especially one of our learning stations (see chapter 5), is based on IBSE and follows CREATIONS features and is set in a suggested effective learning environments. The module can also be extended with arts activities, to integrate a further application of creativity.

Our learning module was designed for 10th graders (mean age 15) at the highest stratification secondary school level ("Gymnasium") in Bavaria, Germany and follows the Bavarian syllabus. It is based on global and local questions and problems concerning biodiversity. In our case, e.g. spruce monocultures. From our point of view, it can also easily be fitted into other countries curricula, by adapting it to local signs of biodiversity endangerment.

4.2 Student needs addressed

According to the Self-determination theory (SDT) of motivation and personality development, there are three universal and innate, basic psychological needs *autonomy*, *competence* and *relatedness* (Deci and Ryan, 2000). The SDT is often applied to educational contexts because it is supposed "that teachers' support of students' basic psychological needs […] facilitates stud-ents' autonomous self-regulation for learning, academic performance, and well-being (Niemiec and Ryan, 2009, p. 133).

Our learning module meets all three students' basic needs. Students experience autonomy, because the activities are based on a learner-centred approach. The teacher takes on the role of an advisor only, who asks questions if necessary but does not intervene in the learning process. With the help of instructions in their workbooks, the students groups are able to do the tasks independently. For each station, they have a time limit of 30 minutes and are responsible to fulfil all obligatory tasks in time.

Furthermore, the module meets the student need for relatedness, because the students are working together in small groups of four, during the whole course of assignments. Every group member has his responsibilities for the group's progress. Students discuss questions and problems and help each other to accomplish the assignments together.

Finally yet importantly, the module fosters the need for competence. During the learning circle, students are occupied with difficult problems and questions. At the end of each station, they are able to answer the initial question or are able to solve the research problem. Having accomplished every task, they are able to connect their recently gained knowledge and will feel be able to explain the most important concepts they have learned.

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5. Learning Activities & Effective Learning Environments

As stated above, students perform the module in a learning circle with a learner-centred introduction phase, four learning stations and a guided revision phase. Fig. 1. illustrates the learning circle. There are different student activities and research questions for each station. The revision phase is not illustrated. In the following, the learning module and its activities will be explained in further details.

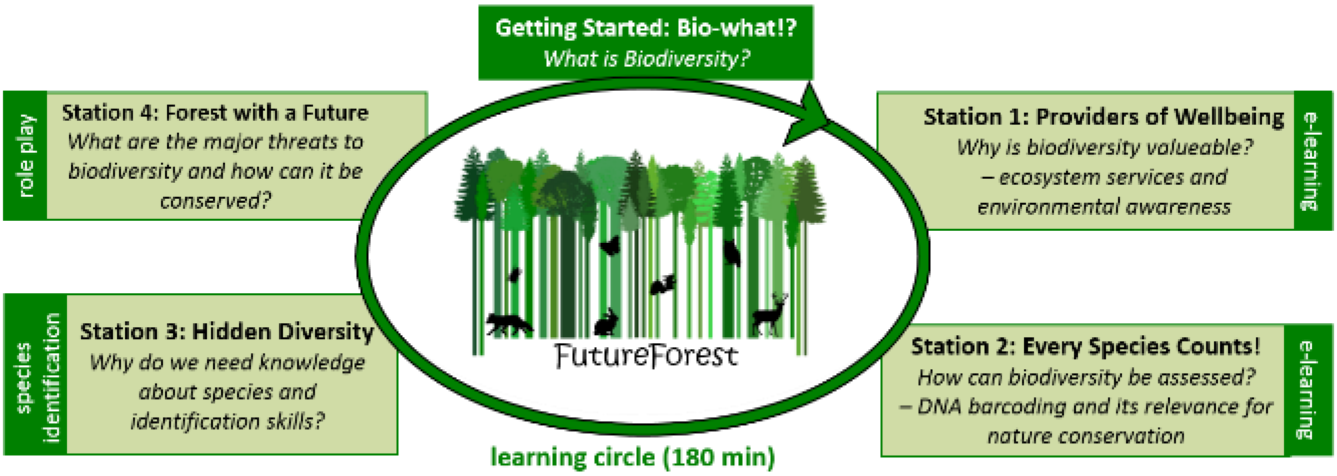

Fig. 1. The *FutureForest* learning circle with an introduction phase and four learning stations. The green boxes display the name of the station, its research question(s), as well as the type of student activity

At first, the students are divided into groups of four people. In contrast to the learning stations, the introduction phase needs a little guidance by the teacher and all student groups do the assignments at the same time. Afterwards, each group starts at one learning station and accomplishes all tasks before they switch to the next station.

- **Introduction Phase: "Bio-what!?"**
  Every group receives an envelope, which contains 21 pictures of different ecosystems (e.g. a desert, a river, a coral reef etc.), various forest animals and several different looking squirrels. Students are asked to arrange the pictures in a meaningful way. Afterwards, several groups describe their result, without any confirmation or rejection by the teacher. The students raise different questions, e.g. "Why do the squirrels have different colours?". Then, each group gets four different short texts about biodiversity and its three levels. Each student is asked to read one text and to share the information provided with the group. Based on the group discussion with exchange of information, the groups are able to revise and rearrange their order of pictures. The different outcomes are then discussed in plenary. The students are now able to answer the questions, which they have raised after they had ordered the pictures for the first time. At the end, the students should be able to formulate a definition of biodiversity with its three levels and write it down into their workbooks.

- **Station 1: "Providers of Wellbeing"**
  The computer-mediated learning station, deals with the question "Why is biodiversity valuable?". Students work with an e-learning tool on a website, which was set up specifically for this purpose. The students get to know the concept of ecosystem services and their dependency on biodiversity.

The first task is to find out the ecosystem services provided by forests and to illustrate them in a mind-map. Afterwards students are engaged with the question how those services are dependent on biodiversity and why biodiversity conservation is on the one hand important for the nature but on the other for humans, as we are the receivers of many ecosystem services and our life is dependent on them. When students have learned about the services and their importance, they have to think about daily strategies for everyone to help to protect biodiversity exemplified by the forest ecosystem. For example, such strategies are to spare paper in our daily routine, to dispose paper properly and to use recycled paper and paper products.

- **Station 2: "Every Species Counts!"**
  At station 2, students work with an interactive PowerPoint presentation, which contains simulations and tasks to be solved. Each tasks requires students to state a question, which they will analyse and answer or will encounter students with a problem to be solved. The overall research question for the students is "How can biodiversity be assessed and why is this important for nature conservation?". They get to know DNA barcoding as the new method of species identification using genetic tools. At the end, students are able to explain the importance of species identification and biodiversity assessment for conservation strategies.

- **Station 3: "Hidden Diversity"**
  At this station, students train their own identification skills by identifying forest soil animals with the help of a microscope or binocular and a simplified identification key. Each group gets eight samples to identify. It is also important that students wright down specific identification features for each soil animal. After having identified all samples, students focus on the question why identification skills are important.

- **Station 4: "Forest with a Future"**
  At the very last station, students deal with the question "What are the major threats to biodiversity?", using the example of the forest ecosystem. Students are faced with a future scenario. They get a text about a forester, who lives in the year 2050 and has planted a monoculture of spruces (a tree species, which is very common in Germany and especially in Bavaria). In consequence of climate change (raised temperatures, less rain and more frequent storms etc.) and his forestry utilisation, the forest is largely devastated. The students are asked to analyse the mistakes the forester has made (e.g. planting a monoculture, removal of deadwood etc.). Afterwards, they get different information cards to be able to further deepen their understanding. Then, they slip into different roles to play an assembly of decision makers and interest groups, who want to find a solution for the future of the forest. During this role play, students are asked for a change in perspective, as every role explains their point of view and wants their interests pursued. At the end of the discussion, the group has to strike a compromise on the future of the forest.

- **Revision phase**:
  There are different options for the revision phase. In our case, the students were asked to formulate questions on aspects, which they did not fully understand during the student-centred learning activities or on issues, where they want to deepen their knowledge. Afterwards the questions where

discussed in student groups with a different composition than during the learning circle. Unresolved issues where then clarified

As described in detail, every station is based on the IBSE approach and begins with its very own research question to be solved during the course of the assignments. In the following table "Learning activities in terms of CREATIONS Approach" (p. 12-16), we chose one station to illustrate the procedure of IBSE. We will therefore only describe Station 4 in further detail and in respect to the CREATIONS features. We regard this station as highly creative and most suitable for the CREATIONS approach, because before, during and after the role-play, students have to think creatively together, share their ideas in a dialogic space, change perspectives and find a common solution to a problem.

Science topic: Biodiversity (Relevance to national curriculum) Class information Year Group: 10th grade Age range: 14-16 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *What do you need?* *Printed material (questionnaires, workbook, worksheets, role cards, information cards), identification key for soil organisms, at least 8 laptops/computers(for the elearning stations), at least four microscopes/binoculars (depending on class size/number of groups), sample tubes, disposable pipettes, pincettes, ethanol* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? in the classroom* *Health and Safety implications? no* *Technology? laptops/computers and microscopes/binoculars* *Teacher support? teacher is needed as an advisor*
Prior pupil knowledge The introductory phase is obligatory for students to learn key ecological terms and concepts (e.g. definitions of a species, an ecosystem, genetic variety, biodiversity etc.). If single learning stations are done separately, an introductory phase is also needed to introduce the key concepts.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

1. Students will receive an overview of the ecological, economic and social value of biodiversity.

2. Based on the example of soil fauna, students will gain an insight into the concept of biodiversity.

3. Students will come to realize, that the ecological knowledge of species and identification skills form the basis of successful nature and species conservation.

4. Based on the example of global climate change and the forest ecosystem, students will develop an awareness of the negative impacts of human activity on biodiversity.

Assessment	**Differentiation**	**Key Concepts and Terminology**
We assessed the module through a questionnaire (pre-post-retention design). It would also be possible to let the individual student groups present their results and evaluate each other's findings.	*How can the activities be adapted to the needs of individual pupils?* Besides the obligatory assignments, there are additional tasks for high-performing students or groups. Further, there is additional, supporting material for low achievers.	**Science terminology:** ecology, biodiversity, species, ecosystems **Arts terminology:** mind-mapping, role play, drawing

Session Objectives:

see individual session project objectives?

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students are working in groups of four. They read a future scenario about the problems of a forester. This raises several questions concerning biodiversity (e.g. "What is the function of deadwood?" or "What is the problem with monocultures?")	has the role of an advisor only (helps out and answers questions, if necessary)	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students are asked to evaluate and discuss the mistakes the forester has made and their consequences for his forest.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	The students read little information texts about deadwood, monocultures, threats to spruces by climate change and bark beetles. Each group member reads one text and shares the information with their group members.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Group members get a role card with necessary information for their role to play. They connect their	has the role of an advisor only (helps out and answers	The students could possibly draw a picture of their perceptions

		pre-knowledge of the previous phases with the new information. Students are doing the role-play. They have a discussion concerning the future use and protection of the forest.	questions, if necessary)	on how the forest should look like in the future (e.g. a nature oriented forest with a high percentage ofdeadwood, many tree and animal species).
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	phase 4 and 5 are done in one step		
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the	In plenary, the students discuss their group results (compromises on the	has the role of an advisor only (helps out and	

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COMMUNICATE: students communicate and justify explanation	scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	future use and protection of the forest).	answers questions, if necessary)	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Together, the groups evaluate the best way to recover, use and protect the forest in the future and connect their ideas to the real world problem of ecosystem endangerment.	The teacher gives hints, asks questions and helps the students.	

6. Additional Information

- Impressions of the module's activities:

Fig. 2. A student at learning station 3, identifying a soil organism (© Jennifer Schneiderhan)

Fig. 3. Students during a group discussion. In the background: the teacher as an advisor (© Jennifer Schneiderhan).

7. Assessment

For the assessment of our module, we used a paper-and-pencil questionnaire. In a pre-, post- and retentiontest, we evaluated the following parameters:

- knowledge gain (25 multiple choice questions)
- scientific motivation (Science Motivation Questionnaire II)
- environmental values (2-MEV) and appreciation for nature
- fascination for biology and natural sciences (FIT questionnaire)
- collaborative problem solving skills and attitudes (FIT questionnaire)

It would also be possible to let the individual student groups present their results and let them evaluate each other's findings.

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8. Possible Extension

Our module conveys fundamental understanding of the concept of biodiversity, its value and endangerment and generates practical knowledge on how to conserve biological diversity. To further deepen their knowledge, it would be possible for students to meet different experts on this interdisciplinary research field. For example, they may have virtual or physical visits to the research centre, where taxonomists and geneticists do the DNA barcoding. They could also meet a forester, a huntsman or an environmental scientist to get a further insight on different perspectives or approaches on biodiversity conservation. These activities would comply with the RRI aspects and effective learning environment of the CREATIONS approach.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.5. Creative modelling of a nerve cell

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Michaela Maurer
Code:	D 3.5	**Contributors:**	
Version & Date:		**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Creative modelling of a nerve cell is a teaching unit in school. The module is related to the domain of Biology and provides selected basic concepts around the topic of a nervous system (.e.g. structure and function, transformation transfer).

1.2 Type of Activity

It is an Educational Activity based on Creativity- enriched Inquiry- Based Approaches (school- based).

It is a local activity.

The activity based on creativity-enriched approach by modeling a handicraft of a nerve cell with different materials (e.g. cable, modelling material, pearls, pipe cleaners, modelling clay and so on). This 'hands-on' activity based on creative thinking derived from student's conception inspired by the following text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998). The activity is student-centered (single or pairwise), while the teacher takes on the role of an advisor only.

1.3 Duration

The learning content was designed for 8th graders (age 13-14), double lessons of twice 45 minutes at the highest stratification secondary school level (`Gymnasium´) in Switzerland following the German-speaking Switzerland syllabus. From my point of view, it can also easily be fitted into other countries curricula, depend on their school level e.g. for 8th graders 'Gymnasium' and for 10th graders 'middle school' in, Germany (e.g. Bavaria).

1.4 Setting (formal / informal learning)

The activity of building a handicraft of a nerve cell is based on a formal learning classroom setting. The students have the possibility to learn in their usual environment. Students need a quiet environment to read carefully the text. The goal is that the text stimulate students to think creatively, sharing their ideas within the group by using all required construction material in the subsequent planning phase to build a nerve cell in the second phase together. To organize the classroom activity, including all the required materials for all participant is easier to handle it in a formal setting. Informal setting like an outreach setting (*e.g.* anatomical museum) are possible in another context.

1.5 Effective Learning Environment

The goal is to build at least a communication of scientific ideas to the audience like the whole class. Furthermore if the result of all modelling handicraft will be shown in a vitrine for example, the audience will be the whole school. The creative and discussing part will be act within and between groups. •

Communities of practice

- Simulations
- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centers (virtual/physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

'Modelling is the essence of scientific thinking, and models are both the methods and products of science' (Harrison & Treagust, 1998). Furthermore, models and modelling take a central place in science education to stimulate the amount of new knowledge during complex themes (KMK, 2013). However, teachers using models in science teaching over 30 years e.g. Hesse (1963). Harrison and colleagues describe the view of science models as a tool for teacher to help them to support the cognitive ability of their students in the learning process. However, it is an educational challenge for teachers based on their class heterogeneity of individuals with different skills (*e.g.* misunderstanding the text, problem to imagine and modelling a structure that is very small and not to see with a human eye or modelling untalented). Apart from that, models are a mentally visualizable way of linking theory with experiment. They enable predictions to be formulated and tested by experiment (Gilbert, 1998). Schwarz and colleagues (2009) concluded scientific modelling as the elements of the practice (constructing, using, evaluating, and revising scientific models). They sum up that building model as a new way to generate knowledge, metaknowledge that guides and motivates the practice (e.g., understanding the nature and purpose of models). To sum up, teachers are able to build heterogeneity groups of student´s they complement together based on their strength and weakness of different skills. Teachers should be detailed prepared before the class section, that especially all materials are available and for each group identical.

2.2 Added Value

Models (Latin: 'modulus' – scale) refers to a system, an object, a phenomenon or a process (Van Driel & Verloop, 1999). It shows either simplify, immaterial or material representation of reality as a whole, a detail or essential elements for demonstrate a structure or special features based on the original or procedures (Meyer, 1990) including a central thinking and working functions in science.

According to the *IBSE* approach, students have the possibility to create their own model in a creative and independent way. Prior knowledge are not necessary. Students get the information from the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998). Students are able to develop their own ideas inductively from the text. The text description provide the opportunity to build questions by their own or within the group e.g. how to looks like a nerve cell, how get a nerve cell information's (dendrites), how to transmit (cell body) and continue the information (axon) to another nerve cell (or muscle cell or gland cell). Students will elaborate the results themselves and discuss within the group. They should practice moreover an applicable knowledge instead of mere factual knowledge. Primary think critically, discuss within the group and share their results within the class is one target goal of this project.

3. Learning Objectives

3.1 Domain specific objectives

The domain specific objectives are to improve students' creative thinking in science via inquiry-based learning and creative investigations and negotiations. The aspects of creative thinking and production were examined in metacognitive processing, the knowledge base, and personality variables (Feldhusen, 1995), a creativity combination of talent, knowledge, ability, intrinsic motivation, and personal traits, additionally influenced by environmental impacts. Models enabling the researcher to derive hypotheses which produces new information about the target as well as models plays an important role in the communication between scientist (Meyer H., 1990) a target goal in this demonstrator example between student group in pairs and within the plenum.

3.2 General skills objectives

This learning module fosters different general skills. In the following, I represent the skills exemplarily:

- understand the biochemical processes between nerve cells and how to transfer an information from part in the body to another part
- developing of social competence throughout communication and cooperation within a group
- sensitization and independent learning
- supporting and promoting the acquisition of skills (problem-solving skill, conflict skill, knowledge through experience
- promoting handicraft skills
- practical and action-oriented approach to planning how to create a nerve cell within a time constraints
- promoting presentation competence
- cognitive increasing expertise via learning of the structure and function of a nerve cell

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The educational activity is based on Creativity-enriched Inquiry Based Approaches and 'hands-on' activities. The learning module takes places in a classroom setting. It provides the concept of a simple function and structure of a nerve cell within a nerve system. Hands-on modelling presents a complex strategy to reach understanding that offers multiple ways for learning and understanding routes to historical discoveries. By creating a model of nerve cell, they learn by doing scientific work. The students have to transfer what they read in the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998) to another cognitive system and this transference helps them to connect the key features of each notion (nerve system).

After a short introduction from teacher's side, the students work best in pairs. They getting the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998) and all required construction materials (e.g. cable, modelling material, scissors, pearls, pipe cleaners, modelling clay). Teacher takes on the role of an advisor from now.

First, each student read carefully the text by his own. The text contains a story including an everyday background with essential information how to transmission an information within the body. Furthermore the text stimulate to think creatively, sharing their ideas within the group by using all required construction material in the subsequent planning phase to build a nerve cell in the second phase together. After this unit, the students can share their results within the class to see the similarity and the difference to other groups. Furthermore they can simulate the transfer from one nerve cell to other nerve cells as a game.

4.2 Student needs addressed

A main principle of the demonstrator is to enable students' engagement to meaningful activities of modelling a nerve cell in detail to understand the fine structure of a nerve cell as a simplified image of reality. Throughout a working process, what students have learned, a discussion session within pair groups and between all groups in a last round of all classmates are crucial to discuss the similarities, the difference and the open question what is unclear how to transform a signal through a nerve cell versus nerve system. Before every group member has his responsibilities for the group's progress. Students discuss questions and problems and help each other to accomplish the assignments together. The students have to transfer what they read in the text to another cognitive system and this transference helps them to connect the key features of each notion (nerve cell and structure). The teacher takes on the role of an advisor only, who asks questions if necessary but does not intervene in the learning process. It is useful if all students see the result of other groups as well (*e.g.* presentation of all nerve cell structure on a table or present the different results via video projector. Independent learning, time management, reflection and group work are crucial prerequisite for effective collaboration in this enquiry-based section.

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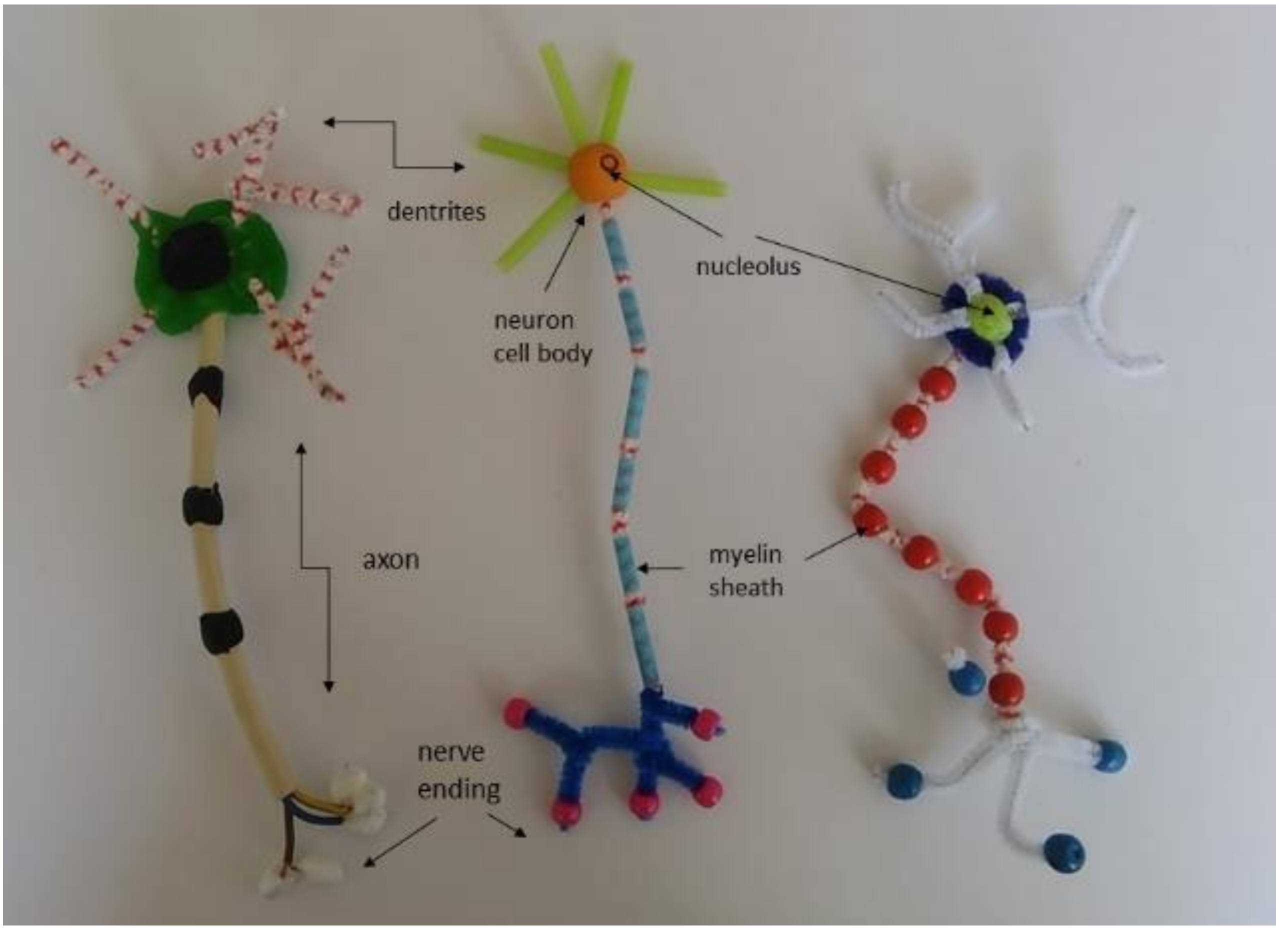
5. Learning Activities & Effective Learning Environments

- Topic: Creative modelling of nerve cell-structure
- Hands-on `experiments´
- Practical and action-oriented approach of a modelling unit
- Discussion and presentation unit
- Social competence and critical facility



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Science topic: Nerve cell within a nerve cell system (Relevance to national curriculum) Class information Year Group: **8th grade (in principal 8-10th grade depend on the national curriculum)** Age range: **13-14 (possible 13-17)** Sex: **both** Pupil Ability: **The scenario allows space for pupils of various abilities to participate**	Materials and Resources *What do you need? (e.g.* printed questionnaires, teleconference, etc.) **cable, modelling material, scissors, pearls, pipe cleaners, modelling clay** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **any classroom are possible** *Health and Safety implications?* **no** *Technology?* **no, maybe visualizer and video projector for debriefing in plenary session** *Teacher support?* **teacher is needed as an advisor**
Prior pupil knowledge **During the modeling phase, students will gain an overview about selected basic concepts around the topic of nerve cell-structure.**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will	

Students get a text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998) with instructions. After reading the text by themselves and discussing its content with a neighbour they do some handicraft work while building a model of a nerve cell in partnership with a classmate. Communication of scientific ideas especially in the context of modelling in science is also given space.

Assessment	**Differentiation**	Key Concepts and Terminology
Only teacher and classmates without questionnaire.	*How can the activities be adapted to the needs of individual pupils?* **The students can choose material and content of their nerve cell independently.**	**representing nerve cell-structure, modelling** Science terminology: **modelling, handicrafts** Arts terminology: **model based learning, model building, modelling space, modelling primitives, formalisms, scientific objects and real objects, object entities etc.**

Session Objectives:

Creative thinking as well as selected basic concepts of the biochemical process how to transform an information throughout a nerve cell system.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students are working in groups of pairwise. They read the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998). This raises several questions concerning 'how does a nerve cell looks like' and how to transfer an information.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students are reading the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998) and discussing how their handicraft nerve cell will be looks like.	has the role of an advisor only (helps out and answers questions, if necessary)	Handicraft: Creating own models of nerve cell-structure.

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Phase 3: **ANALYSE:** students analyse evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Discussing the structure of a nerve cell.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Explain the structure of a nerve cell.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students consider how the biochemical processes talking place to transform an information.	has the role of an advisor only (helps out and answers questions, if necessary)	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	In plenary, the students discuss their group results.	has the role of an advisor only (helps out and answers questions, if necessary)	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students understand the structure of a nerve cells and the biochemical processes.	has the role to lead the discussion within the class	

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6. Additional Information

Materialbox for modelling (Example) and text:

Eine Reise zu den Nervenzellen

Es ist eine klare Nacht. Du liegst an einem Meeresstrand, über dir ein funkelnder Sternenhimmel. Dort befindet sich die Milchstraße mit 100 Milliarden Sternen. Deine Augen nehmen die hellen Sterne am schwarzen Himmel wahr, deine Ohren hören das Plätschern von Wellen. Alles, was du siehst und hörst, wird in elektrische Erregung umgewandelt und über verschiedene Nervenzellen von den Sinneszellen in Augen und Ohren zu deinem Gehirn weitergeleitet.

Dein Gehirn ist die Stelle in deinem Körper mit den meisten Nervenzellen. Es sind 100 Milliarden Nervenzellen - so viele, wie es Sterne in der Milchstraße gibt.

Was machen deine Nervenzellen? Sie stehen im Kontakt mit anderen Nervenzellen, mit Muskeln, mit Drüsen, mit Organen. Sie nehmen Informationen auf, verarbeiten sie und leiten sie weiter. Die Informationen, die die Nervenzellen transportieren, sind keine Worte oder Bilder, sondern elektrische Impulse.

Wie sehen die Nervenzellen aus? Obwohl sie alle unterschiedlich aussehen, gibt es Gemeinsamkeiten im Aufbau. Und die werde ich euch jetzt beschreiben:

Nervenzellen nehmen Informationen mit ihren Drendriten auf. Dendriten sehen im Mikroskop wie dünne, verästelte Röhren aus, die manchmal wie die Äste einer Baumkrone angeordnet sind. Die Dendriten nehmen also die Informationen auf und leiten sie als elektrische Impulse zum Zellkörper.

Der Zellkörper kann rund, dreieckig oder wie ein Tropfen aussehen. An einer Stelle hat er einen kleinen Hügel. Hier werden alle Informationen, die von den Dendriten der Nervenzelle empfangen wurden, verarbeitet. Am Hügel entspringt auch ein stabförmiger Fortsatz, der Axon genannt wird. Der Hügel heißt deswegen auch Axonhügel.

Das Axon leitet die elektrischen Impulse vom Axonhügel bis zu seinem anderen Ende weiter. Dort wird Information auf andere Nerven-, Muskel- oder Drüsenzellen übertragen. Jede Nervenzelle besitzt nur ein Axon, das aber vielfach verzweigt sein kann. Viele Axone sind von Hüllzellen wie von einem Mantel umgeben. Umhüllte Axone leiten die Informationen schneller weiter als nicht umhüllte. In regelmäßigen Abständen hat diese Hülle Lücken. Dort werden die elektrischen Impulse immer wieder verstärkt. Sonst würden sie mit zunehmender Entfernung vom Axonhügel schwächer werden.

Irgendwo hat das Axon ein Ende. Zwischen dem Axon eines Nerven und der nächsten Zelle ist ein winzig kleiner Spalt: Die Synapse. Chemische Stoffe sorgen dafür, dass Informationen über den synaptischen Spalt zur nächsten Zelle gelangen. Synapsen gibt es zwischen Axonen und Muskeln, zwischen Axonen und Drüsenzellen oder zwischen Axonen und Dendriten anderer Nervenzellen.

Inzwischen ist es kalt geworden. Die Sterne leuchten immer noch am Nachthimmel. Treten wir jetzt den Heimweg an, oder machen wir noch ein Lagerfeuer? Auf jeden Fall erhalten jetzt unsere Beinmuskeln vom Gehirn über viele Nervenzellen den Befehl, sich zu bewegen ...

(Unterricht Biologie 213/22. Jahrg./April 1996)

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7. Assessment

For this module there was no evaluation provided. The following list are possible test to evaluate this module in the future:

- Conceptions (pre/post),
- Specific knowledge-test (content specific),
- SMQ II (Glynn, *et al*., 2009),
- CPAC Creativity Test (short version; (Miller & Dumford, 2014),
- role of scientific models (Treagust, *et al*., 2002),
- state emotions (Laukenmann et al., 2003).

8. Possible Extension

- Game of all students based on the biochemical process how to transfer an information
- Handicraft models to exhibit in showcase for the whole school
- Share results via online portal between classes or schools

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D3.2.6 Strategies of Waste Prevention and Resource Management

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Alexandra Stöckert
Code:	D 3.6	**Contributors:**	
Version & Date:	**V1 29.03.2017**	**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.2 Subject Domain

The module is related to the domain of Biology and Chemistry.

STRATEGIES OF WASTE PREVENTION AND RESOURCE MANAGEMENT:

This intervention provides selected basic concepts around the topic of resource management and waste prevention stategies.

1.3 Type of Activity

Our educational activities are based on Creativity-enriched Inquiry Based Approaches. The specific activity is local and not a school-based activity but it consists of the collaboration between school and industry and the content is according to the Bavarian syllabus. The entire module takes place at the waste incineration plant Schwandorf and is aimed at students between the ages of 10-12 years in the ninth grade of the Gymnasium in Bavaria. A visit to the extracurricular learning site Waste-to-energy plant reveals various aspects of energy production from waste. These aspects are made tangible in Schwandorf, the module consists of four "hands-on" sub-units supported by guided learning: an activation unit, an experimental unit and a modeling unit. The modeling unit forms a bridge between the experiments in the two experimental subunits.

1.4 Duration

Per class two hours on one day. All in all 10-15 classes included.

1.5 Setting (formal / informal learning)

The setting is completely geared towards learning in the waste-to-energy plant: formal learning takes place in the school and the experimental units are led by an expert. During implementation, an expert of the waste-to-energy plant is present as a consultant. The modeling unit is more independent (not formal) when students can create a model of a waste-to-energy plant without strict guidelines. Some parts of the module, e.g. the modeling unit could also be taught at school if the material needed is available.

1.6 Effective Learning Environment

The learning scenario takes place at the Schwandorf waste-to-energy plant. At the power plant, students can learn about energy from garbage by doing various hands-on experiments and training individual skills.

• Experimenting to gain insight: Students build a functional model of a garbage power plant and learn how it works.

• Art-based learning scenarios: there are various crisis-related solutions

• Dialogic space / reasoning: The teaching of scientific ideas, especially in the context of modeling in science and the use of creative approaches from nature in industry

2. Rational of the Activity / Educational Approach

2.1 Challenge

Models and modeling are central to science education, especially to stimulate the scope of new knowledge on complex issues (KMK, 2004). In particular, practical experience helps to develop problem solving skills. Indeed, numerous studies (eg, Treagust et al., 2002) have shown that students generally observe models only as visual objects (medial perception). The methodological aspect, in which models serve as changeable mediators between theory and practice, has rarely been studied in science education, although it is an established scientific practice (Grünkorn et al., 2013). Because traditional science education (STEM = Science, Technology, Engineering, Maths) is often associated with negative perceptions, lack of motivation, and learning difficulties, we try to counteract these problems, integrate creativity into art, and construct creative solutions using our innovative model , STEAM (STEM & Arts) could help to spread the enthusiasm in support of individual self-efficacy, as artistic and creative mental skills are needed in all areas of life, and perhaps especially in science

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

A regional waste incineration plant will provide the learning focus, on-site and virtual. A practice in creating a model of a power plant will explain the function of the power plant. Likewise, students should be made aware of cognitive and affective elements in the „Resource Management"-module for the omnipresent topic of sustainability.

The inclusion of society in science and innovation plays an important role, as well as competences in creative approaches of problem solving skills.

As part of an inquiry-based teaching for fifth and sixth graders, students learn in small groups, how to dispose of, reuse or avoid waste in a creative way and to think open minded. In addition to reusable raw materials of garbage, energy recovery from residual waste should be made tangible and understandable.

Students create virtual animations by using webcams, measuring sensors and registered measurement data as live data, which are to be edited and graphically displayed in the sense of competence orientation.

When creating am functional model students feel like a real member of the society. Pupils should be prepared for everyday situations out of the "real life". This kind of teaching aims to educate them to responsible citizens of the society.

3. Learning Objectives

3.1 Domain specific objectives

d) The main aim

The central part of creativity has made science one of the most important cultural achievements, especially in the context of modeling (Van Driel & Verloop, 1999).The main goal of the demonstrator is therefore to improve creative work and problem-solving thinking in science through inquiry-based learning and creative inquiry and intervention. Creativity can be defined as a combination of talent, knowledge, ability, intrinsic motivation and personal qualities that are additionally influenced by environmental influences.

e) Domain specific objectives

Appropriate methodologies for outreach learning are often inquiry-based; Learners describe problems, introduce ideas, describe observations and review hypotheses. Research-discovering learning scenarios tend to emphasize independent, Critic and problem-solving thinking; related challenges are often associated with students' everyday experiences (Sotiriou et al., 2017).

Our students pass the Inquiry Process (described in detail *2.2.* and 5.) while visiting the waste power plant in Schwandorf. Here, a realistic learning situation is created in which students are able to think and explore independently, so a deeper and more sustainable understanding of the learning content should be achieved. Incidentally, learning information should later be transferred into other contexts. For example, a problematic and structured question allows learners to focus on the interpretation of results and on the link between experiment and theory.

An out-of-school learning location like Schwandorf offers authentic and student-centered learning environments where students can creatively develop themselves. At the same time, it allows students to feel like a true member of industry and or science. Thus, analytical skills with the intention of solving realistic problems and providing scientific explanations can be automatically trained and developed. They increase access to scientific thinking and learn scientific concepts in a real learning environment.

f) Additional aims:

Another goal is to ask how students can apply the knowledge about energy and its different forms in the industry and transfer it to mechanical processes in engineering. This allows students to combine their scholastic knowledge with scientific theory and daily life. In this context, it is investigated whether there is an influence of cognitive load (CL) during the learning sessions? In addition, the influence of the variable creativity (Miller & Dumford, 2014) and the scientific motivation (Glynn et al., 2009) are examined.

3.2 General skills objectives

Learning in an outreach waste power plant isn´t refereed as in school. This means a different kind of teaching students and looking for students' difficulties and alternate opinions. The intervention aims `learning by doing´. For this reason skills in art and science should be an important issue in the environment

of building models to explain the function of a power plant. The students should work with their hands to explore nevertheless not only with their eyes.

Scientific support to students personal belongings help to evolve and rise their research skills. Furthermore pupils learn teamwork. This means that they collaborate to a common goal outside the classroom.

This kind of collaboration helps students learn to substantiate their hypotheses with strong scientific evidence, listen to each other, and make joint decisions. Concluding that our model building approach provides a working strategy for a successful STEAM approach by supporting students' research and modeling skills and constructive dialogue skills.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Inquiry Based Science Education plays a key role in science education (Bogner & Sotiriou, 2011).

A guiding principle of the demonstrator was to offer useful learning activities in authentic learning environments, thus enabling and supporting students' engagement with the topics of energy, technology and sustainability. Therefore, a module on sustainability and energy was developed and established at the Schwandorf power plant. The learning content is aimed at pupils of the sixth grade aged 10-12 at the Gymnasium in Bavaria and follows the Bavarian curriculum. The intervention offers selected contents around the topic energy and recycling. The students receive an overview of sustainability and energy recovery from residual waste.

In addition, hand-based modelling offers a complex learning strategy to understand the varied and practical applications of knowledge learned in theory. Therefore, the lesson combines experiments with creative modelling. This means that students, like real developers in the science lab, develop devices for the industry. By creating a functional model of a waste-to-energy plant, they learn to draw through scientific work and inductive conclusions. When designing their models, they must transfer each component from the theoretical blueprint to a new component. Students have to theoretically transfer what they have learned to another cognitive system, and this transfer helps them to combine the key features of each term.

4.2 Student needs addressed

The guiding idea of the demonstrator is to strengthen the students' commitment to useful activities in authentic learning environments. This means that students work in the power plant as a true developer. By creating a functional model for the waste-to-energy plant and learning to work scientifically. At this stage of constructing a function model, they must associate each feature of the theoretical blueprint with a new handle. The students have to theoretically transfer what they have learned to another cognitive system, and this transfer helps them to understand the working principle.

Therefore, students should have some sustainability and energy skills: they should have ideas about key biological and chemical concepts, interest in modeling in science, and social aspects of resource management and sustainability. This together with manual work should be the best approach to creative learning needs with CREATIONS.

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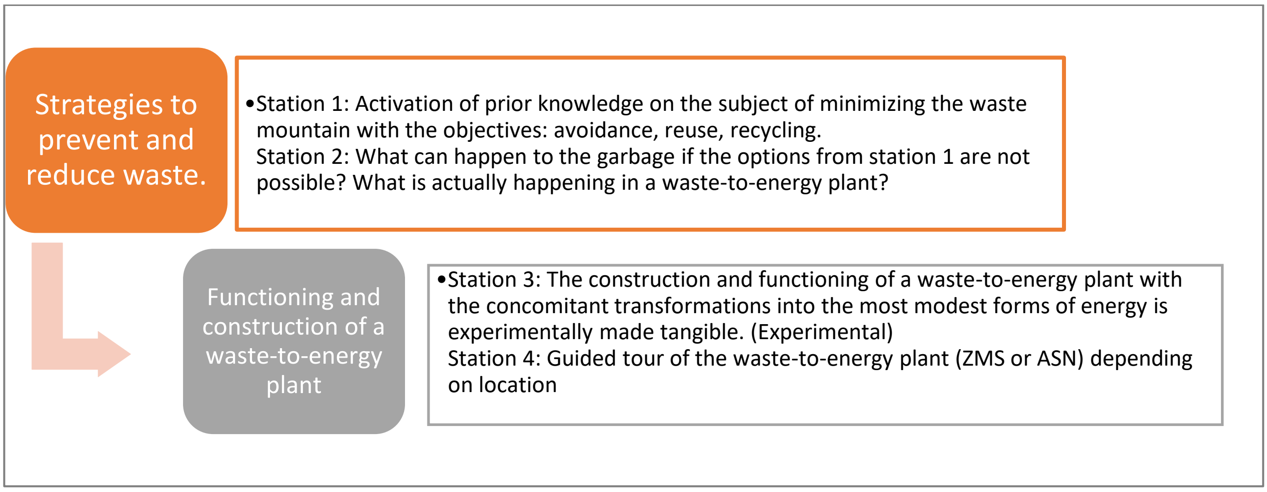
5. Learning Activities & Effective Learning Environments

- Topic: Creative modelling of a waste power plant
- Hands-on `experiments´
- Modelling subunit
- Approaching different levels of understanding the function of a waste power plant



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Science topic: resource management, recycling, sustainability (Relevance to national curriculum) Class information Year Group: 5th grade Age range: 10-12 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **printed questionnaires, materialbox for modelling, workbook with instructions for the experiments** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* in the waste power plant Schwandorf *Health and Safety implications?* Helmet *Technology?* module with guided and independent phases *Teacher support?* Yes, as a tutor learning with students
Prior pupil knowledge **Perception about essential biological and chemical concepts, interest in modelling in science and social aspects of genetics, writing laboratory minutes** Station 1: Activation of prior knowledge on the subject of minimizing the waste mountain with the objectives: avoidance, reuse, recycling. Station 2: What can happen to the garbage if the options from station 1 are not possible? What is actually happening in a waste-to-energy plant? Station 3: The construction and functioning of a waste-to-energy plant with the concomitant transformations into the most modest forms of energy is experimentally made tangible. (Experimental) Station 4: Guided tour of the waste-to-energy plant (ZMS or ASN) depending on location	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will gain an overview about selected basic concepts around the topic of resource management, recycling, sustainability	

Station 1: Activation of prior knowledge on the subject of minimizing the waste mountain with the objectives: avoidance, reuse, recycling. Students discuss about problem solutions on options to avoid waste in small peer groups, afterwards the show their results to all other members of the group. Station 2: What can happen to the garbage if the options from station 1 are not possible? What is actually happening in a waste-to-energy plant? Students should learn and thik about the options you have if waste can not be avoided or reused and to also act in a confident way of sustainability. Station 3: The construction and functioning of a waste-to-energy plant with the concomitant transformations into the most modest forms of energy is experimentally made tangible. (Experimental) Creative solutions of a functional model of a power plant is built by the students and tested in their functional way. Station 4: Guided tour of the waste-to-energy plant (ZMS or ASN) depending on location		
Assessment **A pre-test** (knowledge, CPAC, understanding of scientific Models) **is given before students start with learning activities to evaluate prior knowledge. After passing the final stage they complete a post-test** (knowledge, SMQ)**.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* The students can choose material and content of their functional power plant model independently.	**Key Concepts and Terminology** **Science terminology:** Sustainability, power plant, ressources, modelling **Arts terminology:** modelling, drawing, handicrafts **Modelling terminology:** model based learning, model building, modelling space, modelling primitives, formalisms, scientific objects and real objects, object entities etc.
Session Objectives: During this scenario (exploring a waste power plant), students will learn something about creative thinking as well as selected basic concepts about sustainability and resource management.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	pre-test before participating in the teaching-unit Thinking about how the the mountain of waste can be reduced.	Offering the case of a picture of a big mountain of waste	Create different pictures of solutions e.g. recycle, reuse, recover.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Watching a film about the function of w waste power plant	Teachers reduce their support	

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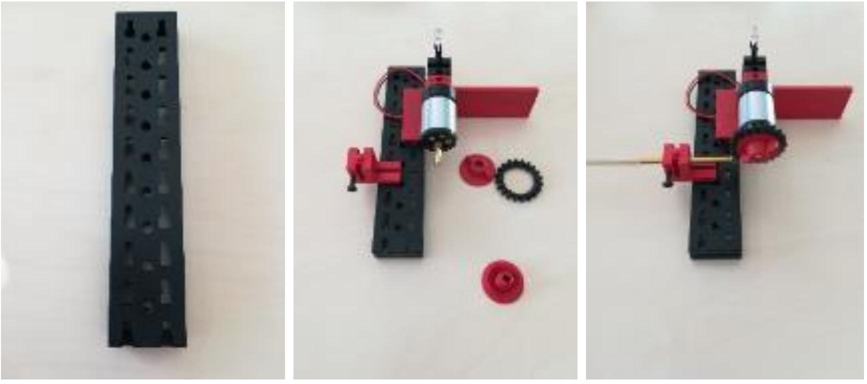
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Discussing the text with an immediate neighbor and answering questions on the film together	Teachers reduce their support, tutoring when needed	**-**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Building a functional model of a waste power planindependently by using the answered questions from Phase 3 and a special materialbox	Teachers reduce their support and give no comments	**Handicraft: Creating own models of a waste power plant. Drawing: Students draw and inscribe their functional models**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Comparing their own results of modelling with the results of the other groups		**-**

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	After modelling students discuss their results and ideas with a scientist at the waste power plant they are not told about right or wrong, but discussing the different models actively	Teachers follow the discussion but give no comments	-
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The module is completed by finding an explanation why some model work better than other models.	Teachers pass a retention-test six weeks later and a résumé at school to complete the intervention for consolidation	-

6. Additional Information

- **Materialbox for modelling (Example):**

- **Impression of a possible functional model:**



7. Assessment

This module is a good example for IBSE based teaching especially in case of the modelling-subunit. First a problem is collected and then the guided version of IBSE is used to demonstrate the effectiveness and effort of this demonstrator. The multisensory learning with handicraft (modelling) and drawing is a possible approach to introduce this in the national school system or even in the curriculum.

The evaluation provides potential questionnaires that should demonstrate the effectiveness: These are a specific knowledge-test, the SMQ (Glynn et al, 2009), the CPAC Creativity Test (short version; Miller & Dumford, 2014). These tests could be separated to pre-evaluation before participating in the waste power plan and post-evaluation directly after the teaching-unit (knowledge, SMQ).

8. Possible Extension

The activity may be held as a small scale local activity, for example different schools or even different kinds of power plants could also participate.

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D3.2.7 Science&Art@School

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Angelos Alexopoulos
Code:	D3.2.7	**Contributors:** Michael Hoch, Stephen Preece
Version & Date:	v1.0, 26 May 2016	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics

1.2 Type of Activity

This activity is a combination of:

- In-school
- Out-of-school including research institute/centre, museum, art space Educational activities based on Creativity- Enriched Inquiry Based Approach, Educational activites that promote school- research center collaboration

1.3 Duration

This is typically a three-day activity

1.4 Setting (formal / informal learning)

The setting is both formal (i.e. school) and informal (e.g. research centre) and engages multiple actors such as science and art teachers, scientists and even parents.

1.5 Effective Learning Environment

- Communities of practice
- Simulations
- Arts-based
- Dialogic space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

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2. Rationale of the Activity / Educational Approach

2.1 Challenge

Consistent with a Deweyan perspective, the key challenge of *Science&Art@School* is to offer school students *transformative experiences* that (1) extend beyond the classroom; (2) transform the learner's perspective; and (3) lead to deep engagement in science (Pugh et al., 2010; Pugh, 2011; Garner, Pugh & Kaplan, 2016). In other words, and to use Pugh et al's (2010: 4) example, the challenge is to provide scaffolding for students to "look at the stars differently at night".

2.2 Added Value

Science&Art@School aspires to be a model of teaching for transformative experiences in particle physics, physics and more widely in science by following three learning-by-doing strategies (Dewey, 1958; Pugh & Girod, 2007; Garner, Pugh & Kaplan, 2016):

1. *Framing scientific content as ideas*. This involves, first, the identification of "big ideas" in physics and particle physics and, second, the presentation of those "big ideas" as compelling possibilities for young students.
2. *Scaffolding re-seeing.* This involves the provision of guidance and support to students in order to help them relate their everyday world through the lens of particle physics and the interwoven role that engineering and technology play in advancing not only research and discovery in the field but also in promoting knowledge generation and transfer with a positive social impact.
3. *Modelling transformative experiences.* This involves teachers, science educators and even art pedagogists being able to demonstrate to students how cutting-edge science, technology and innovation may change the way they perceive and experience the world.

Science&Art@School (Hoch & Alexopoulos, 2014) builds on and expands previous educational activities for high-school students, such as 'hands-on' particle physics masterclasses (Long, 2011; Ouid-Saada, 2012; Cecire et al., 2014). Through intensive, collaborative learning episodes that make use of creative and artistic interventions, this activity offers students the opportunity to delve into transformative, aesthetic experiences (Pugh & Girod, 2007) that are considered to increase their deep engagement in science (Biscotte, 2015).

Importantly, *Science&Art@School* workshops produce artworks by the students themselves. These creative objects may be viewed as "artefacts" and, as such, embody motivated use and experiential value (Pugh, 2011). Selected artworks are then incorporated into the art@CMS travelling exhibitions, thereby serving as sources of motivation for and identification with other school communities from around the world (Alexopoulos et al., 2015).

3. Learning Objectives

3.1 Domain specific objectives

Science&Art@School rests on the idea that particle physicists and artists share fertile common ground in their parallel efforts to understand '*φύση*' (the Greek word for nature). Creating a bridge between these two worlds is worthwhile since it can help students gain a deeper understanding of each subject area. It can also help them think creatively and responsibly about the collaborative scientific effort being done at CMS in CERN, the world's largest particle physics laboratory.

Science&Art@School thus takes the art@CMS concept a step further by bringing young students from the science curricula but also from the arts, humanities and social science curricula together with CMS researchers, science educators and art teachers during extended learning periods in order to help students:

- Understand how scientific research in particle physics works
- Explore how researchers and artists work and view each other's world
- Engage in and create artworks inspired by "big ideas" that drive scientific and technological effort at CMS and CERN
- Develop positive and responsible attitudes towards science, technology, collaboration and innovation in large research infrastructures such as the CMS experiment at CERN.

3.2 General skills objectives

Science&Art@School is situated within the movement for approaching science education in schools from a science, technology, engineering, arts and mathematics (STEAM) perspective. The so-called STEAM movement, as reflected in various national and international initiatives on both sides of the Atlantic, calls for arts integration into science teaching and learning as a catalyst for developing 21st century skills that are necessary to thrive in the information age.

In line with the P21® Framework for 21st Century Learning[1], *Science&Art@School* aims to equip students with the following *Learning and Innovation Skills*:

- Critical thinking (e.g. use systems thinking)
- Communication (e.g. utilise multiple media and technologies)
- Collaboration (e.g. demonstrate ability to work respectfully with diverse teams)
- Creativity (e.g. use a wide range of idea creation techniques such as brainstorming)

The above skills are described in more detail in the P21® Framework Definitions document[2].

[1] http://www.p21.org/about-us/p21-framework
[2] http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

As described in Sections 2 and 3, the principal aim of *Science&Art@School* is not only to inform, inspire and excite young students about how research in particle physics works but also to engage them effectively through learning-by-doing strategies that employ creative and artistic interventions that take place both in school and out-of-school settings. Ultimately, these interventions focus on providing students with transformative experiences that may also result in the acquisition of 21st century learning skills.

To date, twelve *Science&Art@School* workshops have taken place in six countries (Austria, France, Rwanda, Switzerland, United Kingdom, United States) with the participation of more than 600 students from both public and private schools. While the majority of students in those workshops were at senior high school level, the demonstrator may also be applicable to students at junior high school level.

The demonstrator requires the active participation of at least three categories of facilitators:

- Science teacher(s)
- Art teacher(s)
- Scientist(s)

The involvement of science education specialists, art curators, and local educational and cultural authorities or agencies, although not necessary, is welcomed.

4.2 Student needs addressed

By inviting students to think critically, act creatively and behave responsibly, *Science&Art@School* workshops speak directly to the three key aspects of the CREATIONS approach, namely the CREATIONS features, the RRI aspects and the IBSE features. However, unless they address specific knowledge-related needs of the students, they run the risk of failing to meet effectively the learning objectives as specified in Section 3. *Science&Art@School* thus employs a *Deign Framework*[3] that acts as a flexible tool for both the teacher(s) and the student(s) to develop stronger trust and responsibility throughout all stages of the project. This framework rests on three pillars (i.e. Discover, Define, Engage) which, in turn, are associated with the three learning-by-doing strategies described in Section 2.2. In a nutshell, the *Design Framework* acts as a non-prescriptive scaffolding which the learner can use to support his or her concept from brainstorming through realization whilst reinforcing good design practice.

[3] http://www.allminds.ch & http://www.designcouncil.org.uk

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5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics, Physics **Relevance to national curriculum:** **No direct relevance to Swiss curriculum but strong connection to the International Baccalaureate® (IB) Programme as well as to other national curricula** **Class information** **Year Group: Junior high school; Senior high school** **Age range: 12-17** **Sex: Both** **Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** **- Computers, Internet (for the CMS masterclass part)** **- Videoconferencing equipment (for the CMS virtual visit part)** **- Art materials and props (for the production of artworks part)** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **- CMS masterclass can take place in school or CMS institute** **- CMS virtual visit part can take place in school** **- Production of artworks part can take place in school or museum or art centre** **- Exhibition can take place in school or museum or art centre** **Health and Safety implications? None** **Technology? Computers with internet access and videoconferencing equipment for the CMS virtual visit part** **Teacher support? Scaffolding**

Prior pupil knowledge
While no prior knowledge of particle physics is required, a preparatory session initiated by the science teacher is welcomed. In this session, the science teacher is advised to ignite students' curiosity by showing relevant audiovisual material or inviting students to do so at home. The ultimate aim is to initiate the inquiry cycle by posing a "big question" in particle physics that will then be followed up by the students.

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **During this scenario, students will:** **Day 1** **- Be introduced to "big ideas" in particle physics (e.g. The Standard Model)** **- Explore fundamental concepts and methods of particle physics research (Particle accelerators and particle detectors)** **- Analyse real particle physics data with the use of a virtual lab (CMS mini-masterclass)** **- Meet and talk to CMS scientists virtually (CMS virtual visit - optional)** **- Be introduced to the interconnections of science and art** **Day 2:** **- Be introduced to the interconnections of science and art (cont'd)** **- Develop concepts and define design framework for artwork production** **- Implement and produce artworks using a variety of media** **Day 3:** **- Communicate the whole process through means of public outreach (e.g. exhibition)**

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Self-evaluation **- Peer evaluation** **- Portfolio assessment (evaluation template available at Section 7)**	*How can the activities be adapted to the needs of individual pupils?* Science&Art@School is flexible and interdisciplinary by nature and as such speaks well to a diverse group of students.	**Science terminology:** energy, momentum, charge, Standard Model, Bing Bang, hadrons, Higgs boson, dark matter, antimatter, supersymmetry, Planck scale, string theory **Arts terminology:** abstract, acrylic, harmony, futurism, minimalism, mixed media, montage, mosaic, neutral, perspective, pop art, style, symbolism, triptych

Session Objectives: **During this scenario, students will:** **- engage with big questions about the past, present and future of the Universe (e.g. "where do we come from? What are we made of? Where are we going?")**

- attempt to answer and reflect upon these questions, and communicate their interpretation through tools for authentic scientific inquiry but also through creative experimentation and artistic expression

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage in argumentation/dialogue about a scientific topic that may hold social implications but may also influence their personal life choices/decisions Generate with the help of teacher investigable questions through means of authentic scientific inquiry Explore strategies and work structures to answer those questions	Invites students to think of and pose a "big question" in science and particularly in particle physics Ignites students' curiosity by prompting a "big question" in science using audiovisual means (e.g. video) Invites students to think of how scientists and artists approach differently a scientific idea and its social implications.	Brainstorming exercise with science teacher and/or art teacher on how to express a "big question" in particle physics through means of artistic creation

Phase 2 EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Take part in a seminar with professional scientist(s) Learn first-hand from scientists the "what", "how" and "why" of scientific work Start to build conceptual bridges between scientific data visualisation and its artistic interpretation	Organizes a CMS mini-masterclass in school or research institute (http://cms.web.cern.ch/content/how-organize-masterclass) Invites a scientist to run the mini-masterclass Invites an art educator / artist to help students build interconnections between what they learnt in the CMS masterclass and the world of art	Use of Design Framework for defining core idea, art mediums, materials, process and communication under the guidance of art teacher
Phase 3 ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Work 'hands-on' in groups, analyse and visualise real scientific data from the CMS experiment at CERN Apply basic principles and laws in physics (e.g. conservation of energy, conservation of momentum) Embark on artwork production	Science teacher: Facilitates the activity by helping students to connect their analysis techniques with curriculum Art teacher: Invites students to ignite dialogue on the "beauty of science" (e.g. data visualisation) and its potential connection with artistic projects.	Artworks production phase

Phase 4 EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Discuss the findings of the masterclass with scientist and teacher. Develop scientific argumentation Explain their own rationale and design framework to art teacher	Science teacher and art teacher act as facilitators	
Phase 5 CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Make connections between scientific and artistic inquiry Compare different methodologies and skills they used for physics masterclass and artwork production	Science teacher and art teacher act as facilitators	
Phase 6 COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	*Scientific investigation part (Masterclass):* Present the results of their analysis to other students, teacher and scientist as part of the CMS masterclass *Artistic creation part*: Present their artworks during the exhibition; they document in a visually appealing manner the development of their artwork from inception to	Science teacher and art teacher act as facilitators	Art exhibition

		completion. This documentation becomes integral part of the artwork and its communication.		
Phase 7 REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Discuss and reflect upon the evaluation of their work. Explore what worked well and what did not work that well.	Science teacher and art teacher act as facilitators	

6. Additional Information

Additional information on *Science&Art@School* can be found at:

- http://artcms.web.cern.ch (under projects)

Detailed information on the inaugural *Science&Art@School* workshop that was implemented in Graz, Austria, in 2013 can be found at:

- http://artcms.web.cern.ch/artcms/project/high-energy-physics-meets-art/

An indicative programme of a three-day *Science&Art@School* workshop is shown below.

City, Country, Date	
| Day 1 | Participants: Students, Science Teachers, Art Teachers, Scientists. Venue: School or Research Institute	
08:00 – 08:45	**Lecture: The Standard Model** *by Scientist*
08:45 – 09:30	**Lecture: Accelerators and Detectors** *by Scientist*
09:30 – 10:00	**Break**
10:00 – 10:30	**Introduction to CMS Masterclass** *by Scientist & Science Teacher*
10:30 – 11:30	**CMS Masterclass** *by Scientist & Science Teacher*
11:30 – 12:00	**Break**
12:00 – 13:00	**Debriefing of CMS Masterclass** *by Scientist & Science Teacher*
13:00 – 14:00	**Lunch**
14:00 – 15:00	**Introduction to works of art and science** (Part 1) *by Art Teacher*
| Day 2 | Participants: Students, Science Teachers, Art Teachers. Venue: School or Museum or Art Centre	
08:00 – 08:45	**Introduction to works of art and science (Part 2)** *by Art Teacher*
08:45 – 09:30	**Developing concepts for the artworks** *by Art Teacher*
09:30 – 10:00	**Break**
10:00 – 13:00	**Implementation and production of artworks (Part 1)** *by Students*
13:00 – 14:00	**Lunch**
14:00 – 17:00	**Implementation and production of artworks (Part 2)** *Development and completion of artworks* *by Students*
| Day 3 | Participants: Students, Teachers, Scientists, Parents, General Public. Venue: School or Museum or Art Centre	
08:00 – 13:00	**Preparation of Exhibition** *By Students and Teachers*
18:00 – 20:00	**Exhibition Opening** *Welcome speech, introduction to art&science@school workshop, presentation of students' artworks to parents and public*

7. Assessment

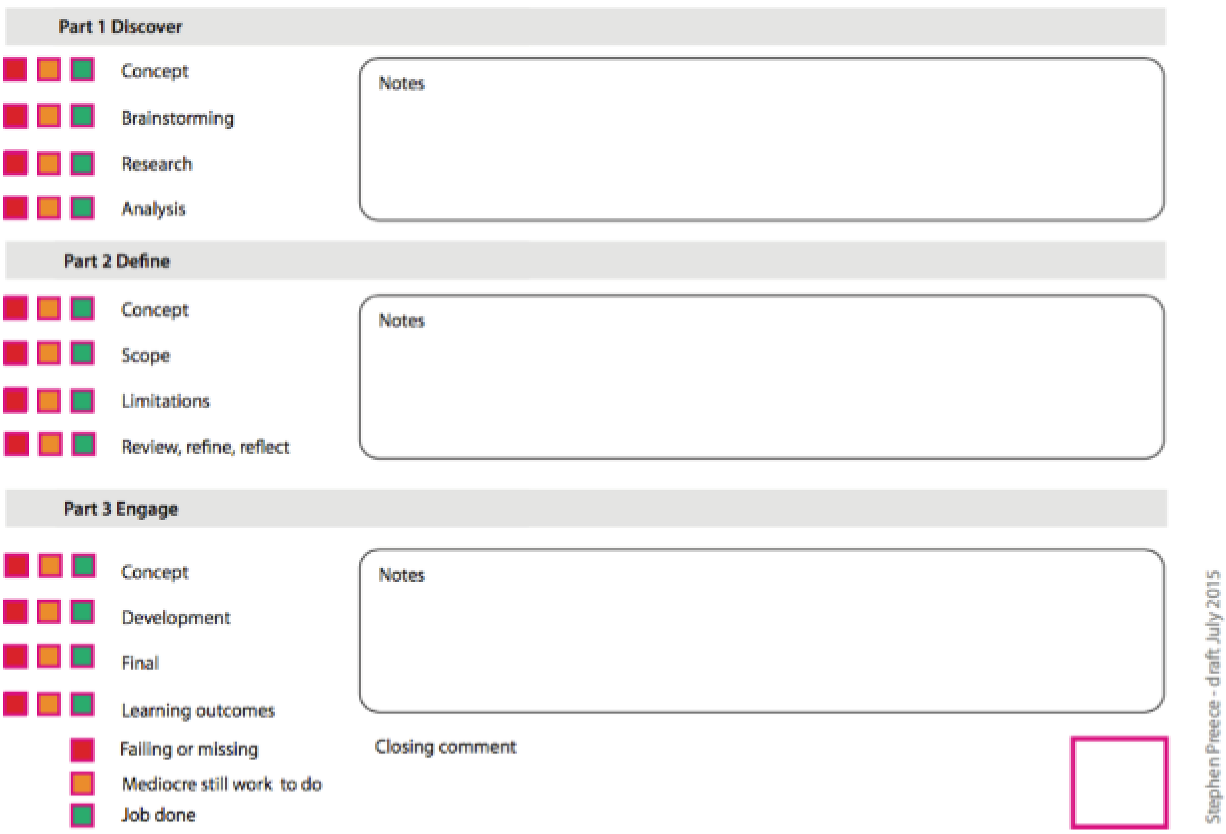
21st century skills, such as critical thinking and creativity, may be quantifiable. Due to the nature of creative and critical thinking and their application, any evaluation must be multi-dimensional. While subject knowledge alone will not suffice, it is a necessary foundation in order to ensure the quality of critical and creative thinking.

Science&Art@School workshops incorpodate a formal evaluation framework. This consists of:

- self-evaluation
- peer evaluation
- portfolio assessment

Science&Art@School rests on the premise that creative ideas need to be realised and it is this process of realisation that is supported by the *Design Framework*. In accordance with the *Deign Framework,* an assessment template that has been used in previous workshops implemented in Switzerland is presented below.

Evaluation Template for *Science&Art@School* Workshop


Part 1 Discover
Concept
Brainstorming
Research
Analysis
Notes
Part 2 Define
Concept
Scope
Limitations
Review, refine, reflect
Notes
Part 3 Engage
Concept
Development
Final
Learning outcomes
Notes
Failing or missing
Mediocre still work to do
Job done
Closing comment
Stephen Preece - draft July 2015

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

In the framework of the art@CMS programme, *Science&Art@School* workshops have been piloted in several schools across six countries in Europe, US and Africa. Speciically, and based on pilot implementation in the International School of Geneva (ECOLINT) over the last three years, *Science&Art@School* is intended to be built as a unit in programmes such as the Visual Arts International Baccalaureate® (IB) Programme[4]. On February 2016, there were more than 5,000 IB programmes offered worldwide across more than 4,000 schools.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.8. CMS Virtual Visits

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Angelos Alexopoulos
Code:	D3.2.8	**Contributors:** Michael Hoch
Version & Date:	v1.0, 27 May 2016	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics

1.2 Type of Activity

This activity is a combination of:

- In-school
- Out-of-school including research institute, science cafè, science fair

1.3 Duration

This is typically a 60’ to 90’ activity

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science cafè, science fair) and engages multiple actors including students, teachers, scientists, parents and general public

1.5 Effective Learning Environment

- Communities of practice
- Dialogic space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Science centres can provide students with authentic experiences in science and STEM by several means, one of which is school visits to their facilities. Accordingly, CERN and the LHC experiments have developed over the last years on-site visits programmes that cumulatively attract more than 100,000 people annually. Specifically, the CMS experiment at CERN welcomes on average more than 20,000 school students per year.

Yet not all schools can afford visiting CERN mainly due to geographical and financial barriers. To overcome these barriers, the CMS experiment has launched a Virtual Visits programme[5] that allows even more students from around the world to enter the world of science, physics and particle physics.

2.2 Added Value

The CMS Collaboration comprises more than 4,000 members from over 190 universities and institutes in more than 40 countries. As a result, communication among research teams takes very often place remotely with the use of videoconferecing tools. By taking advantage of the exact same ICT tools used by the scientists at CMS and more widely at CERN, the CMS Virtual Visits programme can connect even the most remote student communities with CMS scientists located on-site. A second advantage consists of the adaptation of the virtual visit experience to the language requirements of participating schools. A third advantage is that virtual visits can be valuable add-ons to other educational activities for students such as Particle Physics Masterclasses, *Science&Art@School* workshops and other CREATIONS activities such as the Global Science Opera and Learning Science through Theatre.

World map showing CMS Virtual Visits locations. Since September 2014, about 16,000 students have connected virtually with the CMS experiment at CERN and interacted live with physicists and engineers in their native language.

[5] http://cms.web.cern.ch/content/virtual-visits

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

CMS Virtual Visits act as open dialogic spaces that tap into the advantages offered by synchronous communication technology with the aim to inspire and engage the public and especially school students with the world of science, physics and particle physics.

The domain specific objectives of CMS Virtual Visits are:

- Offer students and teachers the opportunity to interact in real time with particle physicists, engineers and other researchers working at the CMS experiment at CERN
- Offer students and teachers the opportunity to visit virtually experimental facilities (e.g. particle detector, control room etc.) and appreciate the magnitude and complexity of engineering and technology involved in big science experiments in particle physics
- Offer students and teachers the opportunity to learn about the human and organizational aspects of big science
- Complement other educational activities for students such as Particle Physics Masterclasses, Science&Art@School workshops and special events (e.g. science fairs)

3.2 General skills objectives

The general skills objectives of CMS Virtual Visits are:

- Students may develop scientific inquiry skills by preparing in advance questions that they will then pose to the scientists during the virtual visit
- Students may develop communication and social skills by learning to interact and dialogue with scientists but also with other students from other locations who take part in the virtual visit
- Students may develop an appreciation of the importance of scientific research in particle physics not only in terms of scientific knowledge gains but also in terms of technology transfer and applications with a positive socioeconomic impact
- Students may break stereotypical views of scientists and also develop identification with the global, collaborative scientific effort being made at the world's largest particle physics laboratory

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of CMS Virtual Visits is to act as interactive, open educational and outreach platform for inspiring and engaging young students and teachers with the science, engineering and technology of big science research infrastructures and specifically the CMS experiment at CERN's Large Hadron Collider.

CMS Virtual Visits achieve this aim through:

- Connecting remotely school communities with scientists and engineers working on site at the CMS experiment
- Complementing other educational activities for students such as Particle Physics Masterclasses and Science&Art@School workshops

4.2 Student needs addressed

Based on quantitative and qualitative feedback from teachers and students, CMS Virtual Visits address satisfactorily the following students' needs:

- Interest in STEM subjects
- Curiosity about big science questions in the field of particle physics
- Sense of belonging to the scientific enterprise
- Identification with scientists, engineers and technologists as professional role models

In addition, CMS Virtual Visits are offered in the native language of the participants and, as such, ease the communication process between scientists and students.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics, Physics, Engineering, Technology **Relevance to national curriculum:** **While there is no immediate connection to national curricula, CMS Virtual Visits can act as valuable scaffolds for standard in-class activities related to the teaching of Physics at senior primary, junior and senior high school levels.** **Class information** **Year Group: Senior primary school; Junior high school; Senior high school** **Age range: 10-18** **Sex: Both** **Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** **- Computer with access to the internet, projector and basic videoconferencing equipment** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **- School classroom or science lab** **- School theatre** **- Science cafè** **- Science fair or festival** **Health and Safety implications? None** **Technology? Computers with internet access and videoconferencing equipment** **Teacher support? Preparation and Scaffolding**

Prior pupil knowledge
While no prior knowledge of particle physics is required, a preparatory session initiated by the science teacher is welcomed. In this session, the science teacher is advised to ignite students' curiosity by showing relevant audiovisual material or inviting students to do so at home. The material is in electronic format and is provided to the teacher in advance. The ultimate aim is to initiate the inquiry cycle by posing a "big question" in particle physics that will then be followed up by the students during the virtual visit.

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*
During this scenario, students will:

Assessment **- Evaluation (quantitative & qualitative) by the teachers in the form of online questionnaire and reports**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* CMS Virtual Visits are customized to the students' learning needs according their age as well as their native language.	**Key Concepts and Terminology** **Science terminology:** experiment, accelerator, detector, particle collisions, calorimeter, GeV, hadrons, leptons, Computing Grid, radiation, discovery, Higgs boson, Bing Bang, histogram, physics events, medical physics **Arts terminology:** N/A

Session Objectives:

During this scenario, students will:

- engage with big questions driving scientific research in particle physics.
- learn about the science, engineering and technology involved in particle physics experiments
- embark on dialogue and discussion with scientists in real time

Learning activities in terms of CREATIONS Approach
NOTE: CMS Virtual Visits speak only to Phase 1 and 2 of the Inquiry Cycle

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION: students investigate a scientifically oriented question**	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or	Engage in argumentation/dialogue about a scientific topic that may hold social implications but may also influence their personal life choices/decisions Generate with the help of teacher investigable	Invites students to think of and pose a "big question" in science and particularly in particle physics to a scientist Ignites students' curiosity by prompting a "big question" in science using	Preparatory exercise with science teacher aimed at classifying questions into categories such as: - science - engineering and technology

	through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	questions that may want to clarify with a scientist and explore further in the context of e.g. particle physics masterclass	audiovisual material provided during the preparation for the virtual visit Invites students to think of how physicists, engineers and technologists may approach differently a scientific idea and its social implications.	- career and life
Phase 2 EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Take part in a virtual visit with professional scientist(s) Learn first-hand from scientists the "what", "how" and "why" of scientific work Start to understand the career path of a professional scientist and the different professions involved in big science	Organizes a CMS Virtual Visit (http://cms.web.cern.ch/content/virtual-visits)	
Phase 3 ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.			

Phase 4 EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.			
Phase 5 CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			
Phase 6 COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7 REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			

6. Additional Information

CMS Virtual Visits webpage (including information on technical requirements and "how to book" a virtual visit for your school)

- http://cms.web.cern.ch/content/virtual-visits

A paper on CMS and ATLAS Virtual Visits presented at the 2015 EPS-HEP Conference

- http://cds.cern.ch/record/2132292/files/ATL-OREACH-PROC-2016-003.pdf

An article on the CERN website on a CMS Virtual Visit

- http://home.cern/students-educators/updates/2014/02/students-visit-heart-cms-detector

Repository of CMS Virtual Visits (including preparatory materials, reports and feedback from participants and recorded videos of virtual visits)

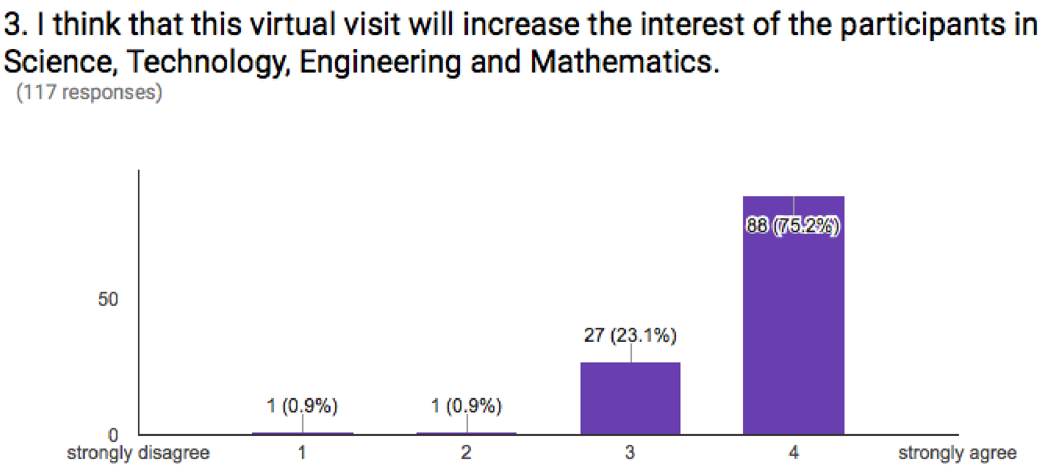
- http://indico.cern.ch/category/5975/

7. Assessment

CMS Virtual Visits are systematically asssessed by teachers who are invited to fill out an online questionnaire after the completion of the event. In this questionnaire, they are invited to:

- express their level of satisfaction with the technical and organizional aspects of the event
- indicate whether and the ways in which they prepared their students for the event
- rate the quality of the information material that was provided to help prepare the students
- indicate the extent to which the event:
  - met their own expectations
  - was appreciated by the students
  - may have a positive effect on the students' interest in STEM
- indicate the scientists in terms of their communication skills
- indicate their overall satiscation with the event
- indicate (in open ended manner) any follow-up plans

Overall, teachers' feedback has so far been positive across the above areas. For example, as shown in the graph below, the majority of teachers (75%) agree strongly that this activity is likely to increase their students' interest in STEM.



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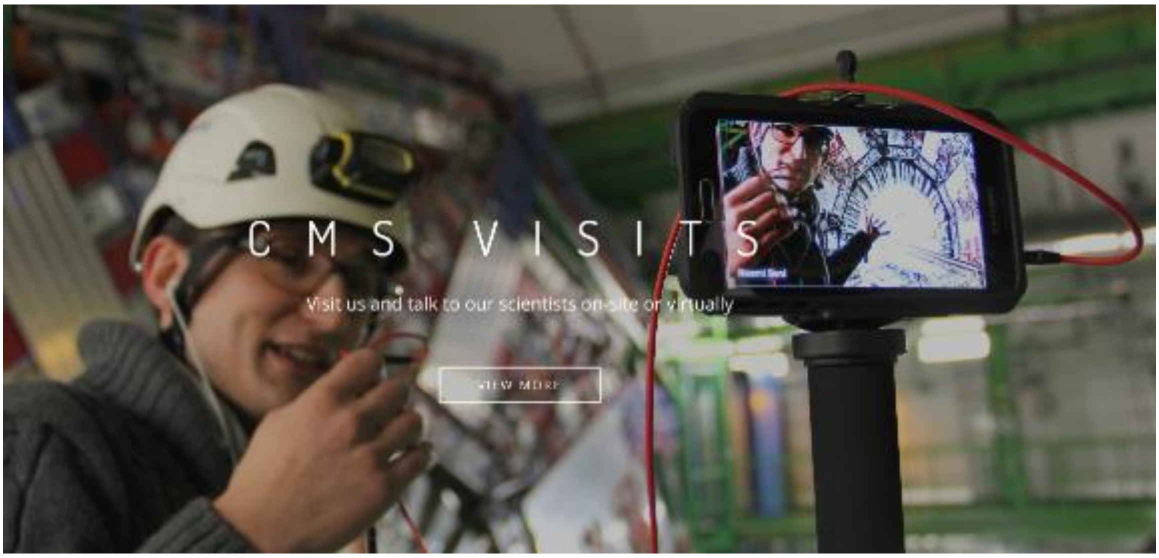
8. Possible Extension

As mentioned in Section 2.2, CMS Virtual Visits represent a valuable add-on activity that can be embedded into and enhance other CREATIONS demonstrators including:

- Science&Art@School workshops
- Particle Physics Masterclasses
- Learning Science through Theatre
- Student Parliament
- Global Science Opera and GSOrt
- Summer Schools
- Etc.

In sum, CMS Virtual Visits can complement CREATIONS educational activities at local, national and international level.



CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.9. From Microcosm to Macrocosm

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Ioanna Kasampa	
Code:	D 3.9	**Contributors:** Angelos Alexopoulos	
Version & Date: V1.0 15/05/20128		**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

- Introduction to scientific thinking
- Simple science theory and methodology
- Physics experiments with everyday materials
- Introduction to cosmology
- Introduction to particle physics

1.2 Type of Activity

- Educational activities based on creativity-enriched inquiry-based approaches (school based).
- Educational activities that promote school- research center collaboration.(like a little science fair at the end of the year)
- It is both local and national activity, because there is a strong collaboration among schools, classes and educators from different places in Greece.

1.3 Duration

Typically 3 to 4 didactic hours per week over the duration of a school year

1.4 Setting (formal / informal learning)

Both formal and informal learning through the activities.

1.5 Effective Learning Environment

- Communities of practice: Children work together in an inquiry-based environment of science activities. They contact and talk with science teachers and astronomers.
- Arts-based: Students created crafts and hands on activities by using their imagination and they expressed themselves.
- Dialogic Space / argumentation: Through debates and questioning students called to express their scientific way of thinking and arguing.
- Experimentation (Science laboratories): Experimentation was a very often process in order to lead to conclusions that help them to understand the science laws and phenomena.
- Virtual visits to research centers such as a virtual visit to CMS experiment at CERN
- Communication of scientific ideas to audience: A little presentation in a form of a science fair at the end of he school year in order to communicate the activities implemented throughout the school year.
- Collaboration with local scientists: Lesson on astronomy by an astrophysicist from the National Observatory of Athens and a night sky observation in collaboration with local community of astronomers.
- Performances in theatre and art: Creation of a black theatre about the macrocosm and the microcosm.

has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Every primary school has its unique challenges to tackle in their effort to inspire and engage pupils with science. This is especially the case of small rural schools located in remote islands where students have limited stimuli and resources available in their out-of-school environment to develop interest in and experiment with "big ideas" in science. In addition, there is the challenge of developing 21st century skills such as collaboration and creativity. Students need to learn from an early age how to cooperate with each other but also how to overcome deeply rooted stereotypes such as the role of women in science. Finally, they need to get familiar with different ways through which they can express themselves and communicate their thoughts and feelings with their friends and the local community.

The above challenges acquire special weight and significance when combined with the selection of pedagogical approaches to "big science" teaching learning. How can, for example, a primary school teacher convey in a simple but not simplified way advanced and complex particle physics experiments, like the ones that take place at CERN, to 9-111 year old students? Last but not least there is the challenge of fitting those approaches with the National Curriculum which currently offers little flexibility.

2.2 Added Value

The demonstrator *From Microcosm to Macrocosm* and its application provides primary teachers with a wide array of methods and approaches to use in class in order to cope with the above challenges and to work effectively with the students. The primary science education programme *Playing with Protons* contributes to that effort by enriching pedagogical practice with creative, hands-on methodologies through which students can, in turn, get engaged effectively with science, technology and innovation.

Furthermore, the element of working in groups and collaborate to create something or to execute an experiment can help the students become more enthusiastic in working together and share roles and responsibilities in teams.

In addition, the demonstrator holds added value for it proposes an student-friendly way of approaching science in class. The students become not only enthusiastic with the object and the activities but also they have the opportunity to widen their horizons in multiple ways and to realize that despite living in a small village of a remote island in the Aegean Sea, they can come closer to new experiences, knowledge, cultures and the global language of science.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the teaching and learning process are:

• To realize that matter is made up of elementary particles which are structured into larger

particles, for example protons, neutrons and eventually atoms,

• The study of particles is also a long story of scientific creativity, innovative thinking, international collaboration and technological development.

• To explain the methods that physicists at CERN follow to understand the fundamental

structure of the universe and how universe works.

• To explore CERN sites and learn about the role of CERN in advancing research in particle

physics and its applications in everyday life such as in cure of cancer .

• To explain in a simple way how the Large Hadron Collider (LHC) works and create models of it.

• To understand that particle physicists collide particles to reveal their inner structure.

• To explain in a simple way how particle detectors work and what is their role in the CERN experiments.

• To realize that the universe is, to a very large extent, filled in with dark matter and dark energy about which scientists until now know very little.

• To make research and learn about space and planets.

• To understand some fundamental laws of physics and to recognize them in everyday life through simple examples.

All the above are based on the six assertions made by Eshach & Fried (2005) about STEM application to primary school students.

3.2 General skills objectives

The demonstrator has the following general skills objectives for students:

• Participate actively and critically in the process of understanding scientific concepts and phenomena by using basic methods of analysis, evaluation and synthesis of a situation. Through hands-on experimentation with everyday materials, the students define a challenge (e.g. design and assemblage an electrical circuit to be used for a particle accelerator mock-up), generate alternative solutions, evaluate their pros and cons, and finally implement and follow up on their solution.

• Develop creative skills and express themselves through arts, by taking part in creative activities such as drawing and designing, storytelling, model making and theatrical acting.

- Develop spirit of cooperation and teamwork. The students are divided into workgroups (four to six students per group) and develop a group identity around common goals and shared tasks to be performed throughout the duration of the program.
- Develop communication and presentation skills by meeting up with professionals, parents and local communities. Each group is also asked to present their progress to the rest of the class quite often. Finally, upon the completion of their projects, all groups present their work and answer questions by the teacher and their classmates. At the end of the school year they present their work to their parent and local society at an open event.
- Deal with mistakes and take risks. The activities described in this demonstrator and especially the scientific method taught during simple experiments can help students understand that mistakes is the best way to learn and improve. The students realize through their involvement with hands-on experimentation that trial and error is inherent in the research process.. Emphasis is thus given on the process and not the end result.

4. Demonstrator characteristics and Needs of Students

4.1Aim of the demonstrator

According to the above challenges and by following some of the CREATIONS features but also the RRI and IBSE features, this demonstrator has multiple aims. Is a description of the planning and the activities applied during the school year in two grades of 3rd and 5th of school of Nenita, focused on science way of thinking, experimenting, creating with everyday materials, researching from different sources and presenting the results. Demonstrates also the methodology and the techniques that used during the activities in the process of teaching and learning.

4.2 Student needs addressed

The needs that appear are different and multiple according below:

- *Social:* Learning how to work together as a team and to cooperate in order to present results successfully.
- *Communication:* Students have to cope with a research problem and to present the results.
- *Inquiry and creativity:* Students engage in activities involving inquiry-based learning.
- *Cognitive and emotional:* Students acquire knowledge about the physical world and the universe and how it works. They also understand the big achievements of humanity in order to explore nature's mysteries, CERN's experiments and their contribution to a better understanding of the natural world. They also satisfy their curiosity about the structure of the Cosmos and the way scientists try to decode Universe's secrets. They also learn to form and present arguments concerning simple scientific phenomena. Finally, they develop a sense of self-confidence and pride in getting to know and communicate complex scientific concepts.
- *Creativity:* The students express their understanding by choosing their own way of creating an artifact or simulation inspired by a natural law, phenomenon or scientific idea. They also build models and constructions that represent something they have learned. Finally, they employ their creativity by trying to create not as real as possible but as precise as manageable.

5. Learning Activities & Effective Learning Environments

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Science topic: Particle Physics, Physics, Astrophysics, Cosmology, Engineering, Technology

The above topics are relevant to the the Greek National Curriculum of Science and Maths at 5th and 6th grades.

Class information: 3rd and 5th grade at the primary school of Nenita, Chios, Greece.

Year Group: Middle and senior primary school students.

Age range: 8-9 & 10-11

Sex: All

Pupil Ability: The scenario allows space for pupils of various abilities to participate according to their relative strengths and weaknesses.

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Materials and Resources:

- everyday materials for simple physics experiments
- power point presentations and additional printed information material
- videos about all the above topics
- internet connection and projector
- extra hours
- simple materials for art activities (e.g. drawing, model making, game playing)
- various props for theatrical performances

Where will the learning take place? On site or off site? In several spaces*?*
science laboratory, drama space, in class, in school yard etc.

Health and Safety implications? No health and safety implications.

Technology? internet connection, PCs, tablet, projector.

Teacher support? The teacher supports and helps groups and individuals during the activities when needed.

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Prior pupil knowledge: Students have a general but on in depth knowledge of the natural world. They understand some of the natural laws just from experience. While no prior knowledge of particle physics or astronomy is required, the whole inquiry is based on triggering student enthusiasm and curiosity.

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Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will:

Session 1: Scientific thinking
By the end of this session, students are expected to understand:

- What are the basic step of scientific process?
- What is scientific thinking?
- What is experiment?
- Why are scientist experimenting?
- How can we connect the steps of experimentation?
- How can we make conclusions and connect them with real life?

Session 2: Elementary Particles
By the end of this session, students are expected to understand:

- What are the basic constituents of matter?
- What is the structure of the atom?
- How small is the atom and its basic constituents?
- Who were the scientists who discovered the atom and its basic constituents?
- What are the fundamental forces in nature by which matter is effected?
- What is the Standard Model in particle physics?

Session 3: Cosmology
By the end of this session, students are expected to understand:

- What is the Universe made of?
- How does the Universe evolve?
- Why is the Universe so big and old?
- How do we know the age of the Universe?

- How does light travel across the Universe and why does it appear in our eyes in various colours?
- How do galaxies move within the Universe?
- Who were the first scientists who helped us understand how and why the Universe expands?
- What scientific experiments are currently carried out to help us understand better what is the Universe made of?
- What is our Solar System and which are the planets of it?
- How important is the planet Earth for us?

Session 4: CERN: Accelerators, Detectors and their Technological Applications
By the end of this session, students are expected to understand:

- What does the acronym CERN stand for?
- How many countries do take part in CERN's experiments?
- Why are there so many physicists and engineers at CERN? Are there other professions involved in CERN?
- What is the Large Hadron Collider?
- What are the main LHC experiments and what do they study?
- What are the important scientific discoveries made at CERN?
- How does a particle accelerator work?
- How many particle accelerators do exist at CERN and what are the main differences between them?
- Why do scientists smash protons with each other at the LHC?
- How do scientists detect the results of particle collisions at the LHC?
- What are the main components of a particle detector and why are particle detectors at CERN so big?
- Why are the LHC and the particle detectors built underground?
- What kind of scientific data do scientists retrieve from the LHC experiments and how do they perform their analyses?
- In what ways do the experiments at CERN benefit our everyday life and society?

Session 5: A journey into the Universe (a theatrical play)
This session builds on the knowledge that students have acquired in the previous 4 sessions. During the preparations for a theatrical performance students write the script and the presentations, create the crafts for the black theatre (planets, stars, galaxies, words, atoms, protons etc.), learn how to perform bby using the black theatre technique.

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Evaluation (quantitative & qualitative) by the teacher in the form of questionnaires, students' workbooks, diaries and presentations	*How can the activities be adapted to the needs of individual pupils?* The activities are characterized by openness, experimentation and flexibility and are thus inclusive to all students	**Science terminology:** atoms, protons, neutrons, electrons, quarks, bosons, Higgs particle, CERN, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, electromagnetism, forces, solar system, planets. **Arts terminology:** collage, drawing, comics, model making, theatrical performance, stand-up comedy, dance, music, theatre, black theatre.

Session Objectives:

During this scenario, students will:

- engage with big questions driving scientific research in particle physics, physics, astrophysics and cosmology.
- learn about the science, engineering , technology and history that are related toparticle physics, physics and astrophysics experiments
- embark on hands-on learning experiences with simple, everyday materials
- embark on model making, game playing and problems solving
- collaborate with others
- embark on artistic activities such as drawing, comic making, stand-up comedy, dance and theatrical performance

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions (How old and big is the universe? From what are everything we feel made of?). Watch videos and use the web to explore evolution.	Will use challenging questions and collect the prior knowledge from the students by using a piece of paper and their notes about what they are thinking. - Are the galaxies moving? (session 2) - What is the atom? (session 1)	First drawings during the collection of the prior knowledge.

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			After that, watch impressing videos about how big an atoms is (session 1), how long distances are in universe (session 2) and where is Cern and how big is the LHC (session 3).	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students work in groups and explore with the help of the teacher simple ways in which they can describe or reenact a natural phenomenon (e.g. expansion of the	Teacher follows up on students' questions and provides guidance concerning sources of evidence that can help students to	Collages and drawings can be applied in order to depict the evidences that they find out during the work.

		universe with the use of a balloon, collision of particles with the use laser beams and flour, states of mater with experimenting with water)	observe the every single detail. All the above through a joyful process with everyday materials.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue*with each other and the teacher to support their developing understanding.	Students discuss in groups in order to express their findings and present their evidences.	Teacher is supportive through this stage by encouraging the groups to be as much analytic as they can.	None at this stage
Phase 4:	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative	Students are forced to analyze and synthesize their ideas	Teacher facilitates and	Mind maps that can enriched with

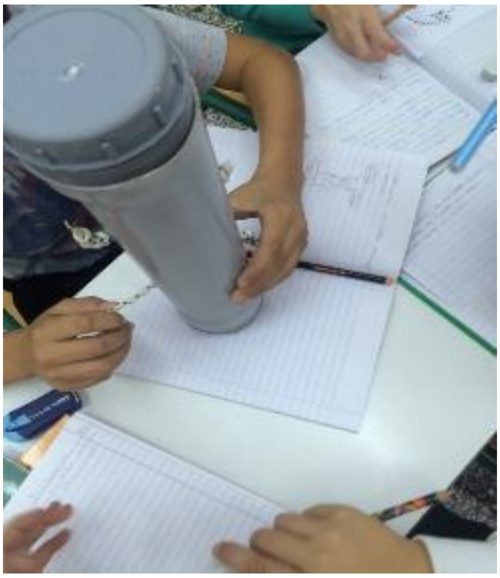
EXPLAIN: students formulate an explanation based on evidence	merits of the explanations they formulate, *playing* with ideas.	by using deferent techniques of presenting their ideas through the different groups.	supports as required.	artistic drawings and picture collage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing*('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary*knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	In this stage students have to make connections with prior knowledge or with other subjects by using the new knowledge. They also can write down these connections by using a notebook or a portfolio.	Teacher facilitates and supports as required in order to force students to make these connection. Also, can make some references in order to help this ability.	Mind maps with these connections.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are invited to present to their classmates but also to scientists (through videoconference or in-situ) their	Teacher give guidance and help in order to present and communicate in appropriate	Models, drawings, theatrical play, dance

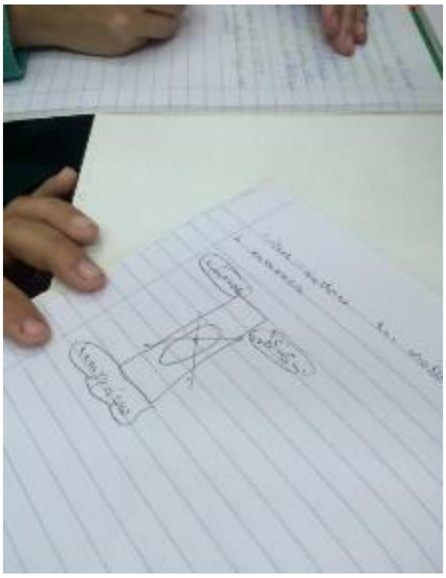
		creations, observations and justifications. They will also make some open days and activities in order to present what they do to their parents and the whole school community.	way their own ideas and creations.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the newly acquired knowledge. At the end of the fourth session as well as to evaluate the process and learning experience	Teacher initiates the evaluation through dialog and collects and acts through feedback.	None at this stage

6. Additional Information

Photographic material from all sessions with the participation of 3rd and 5th grade students at the Primary School of Nenita, Chios, Greece.

Session 1: Scientific thinking



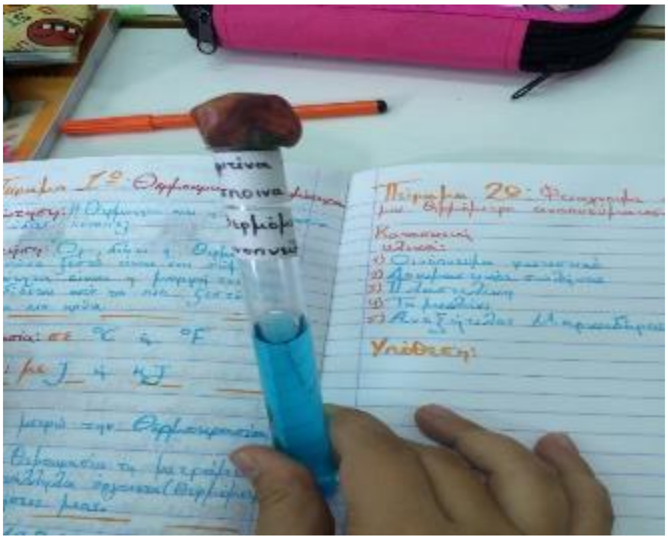


Black box in 5th Grade, an activity presented originally by the Perimeter Institute at the "Playing with Protons" CPD course for Greek primary teachers at CERN

Mystery box in 3rd Grade.

The students try to make predictions and

observations about the content of the box.



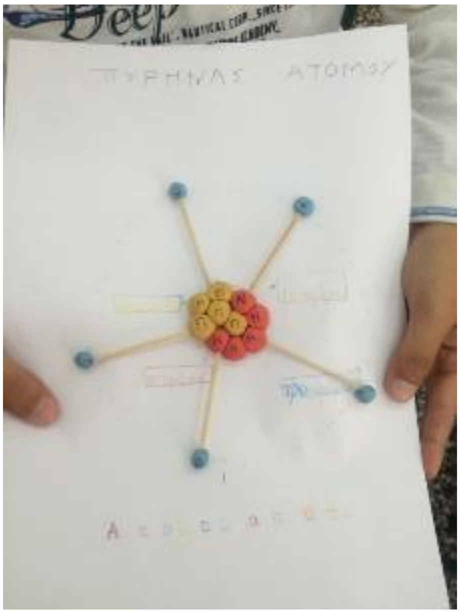
Experiments with temperature by creating our own thermometers.

S has received funding from the European Commission HORIZON2020 Programme

Experiments with temperature, pressure and electricity by 5th grade students.

Eratosthenes's experiment at the yard of Museum of Masticha in Chios.

Session 2: Elementary Particles



Construction of atom models by 5th grade students

has received funding from the European Commission HORIZON2020 Programme

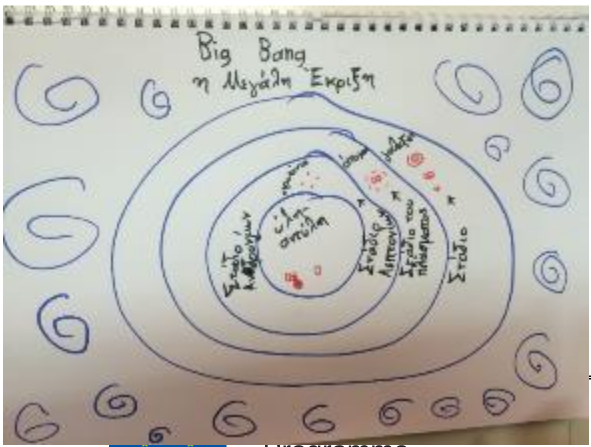
Construction of molecule models by 5th grade students

Artistic creations of different states of matter by 5th grade students

Studying the Standard Model of particle physics by 5th grade students

A 5th grade student draws the structure of a proton

Session 3: Cosmology



Drawings of the Big Bang by 3rd grade students

Creations representing the stages of the Big Bang by 5th grade students

Play-based activity with balloons in order to simulate and understand the expansion of the Universe.

3rd grade students watch a video about astronauts' life in the International Space Station

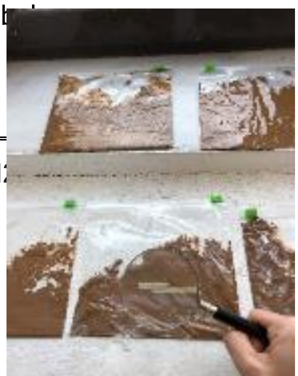
5th grade students learn about gravity and gravitational waves by playing the elastic bed sheet space-time wrapping demo (source: https://www.youtube.com/watch?v=MTY1Kje0yLg)

3rd grade students build a model of the solar system using Play Doh.

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**


3rd and 5th grade students "create" asteroids with everyday materials

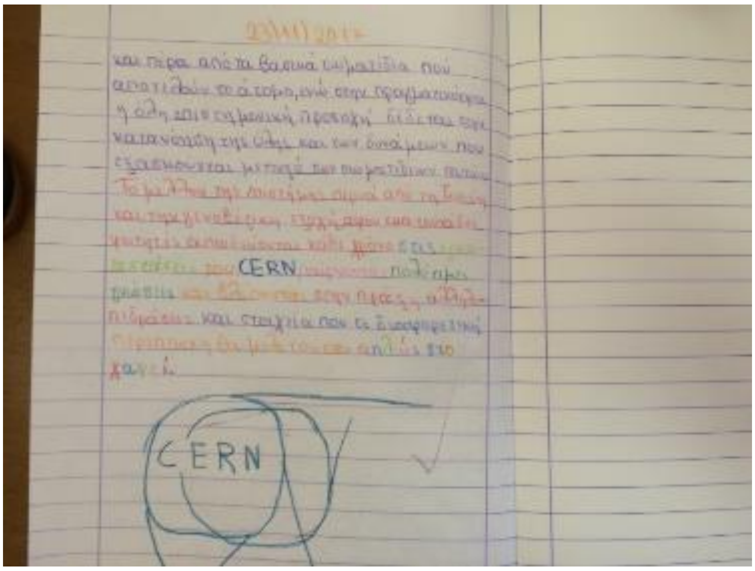

ex neb

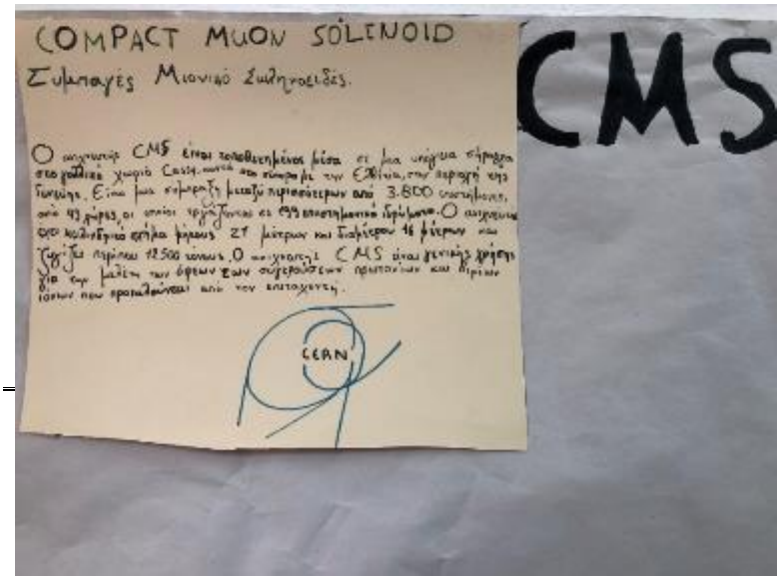



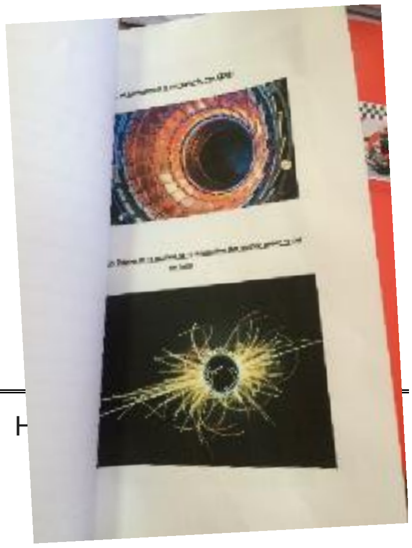
Making predictions about planet Mars and experimenting with a sample of soil from Mars.

Night sky observation organized by the local astronomy club.

Session 4: CERN: Accelerators, Detectors and their Technological Applications





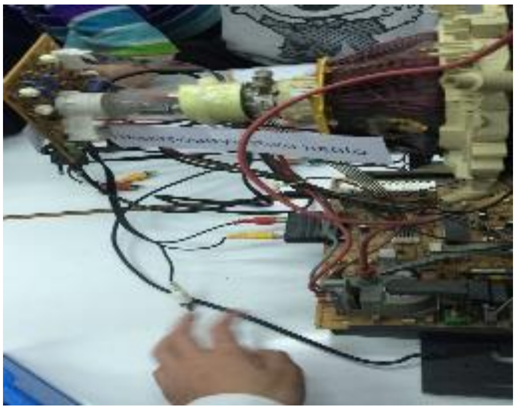


Information collection about CERN by 5th grade students

5th grade students draw a model of the CMS detector

5th grade students draw and study collisions in the CMS detector

Simulating data analysis from collisions according to the Standard Model of particle physics



5th grade students compare the accelerator in a TV with CERN's particle accelerators

5th grade students use LEGO bricks to build model of the LHC and detector

Session 5: A journey into the Universe (a theatrical play)

3rd grade students during the rehearsals of the black theatre play entitled "A journey into the Universe".

7. Assessment

The demonstrator has been evaluated quantitatively by both students and teachers in accordance with CREATIONS assessment protocol that requires the pre- and post-intervention use of the SMQ II questionnaire for students and the VALNET (plus open questions) questionnaire for teachers. More details on the above tools can be found in Deliverable D6.2. The demonstrator also includes qualitative assessment tools in the form of self-assessment by the students (e.g. notebooks, diaries and class discussions after the execution of simple experiments and related activities).

8. Possible Extension

A possible extension of the demonstrator could be the involvement of an astronomy expert in order to help both teachers and students delve deeper into the world of Cosmology and Astronomy. The demonstrator would also be benefited by an international cooperation with educators from other countries that run similar activities in order to exchange ideas, discuss, interact and get feedback from different curriculums, backgrounds and educational systems.

9. References

- Playing with Protons CDP Course [https://indico.cern.ch/event/544827/]

- CERN website [https://home.cern]

- CMS experiment website [https://cms.cern]

-Perimeter Institute website [https://www.perimeterinstitute.ca]

- UCL Institute of Education website [http://www.ucl.ac.uk/ioe/departments-centres/departments/education-practice-and-society/science-capital-research]

D3.2.10. Adventures of a Ferret at CERN

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Fotini Siligardou
Code:	D 3.10.	**Contributor:**	Maria Loumbaki
Version & Date:	v.1.1, 26 Sep 2017	**Approved by:**	NKUA

Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics, Astrophysics, Cosmology, History of Science, Engineering, Technology, Computer Programming

1.2 Type of Activity

This demonstrator focuses mainly on in-school activities.

1.3 Duration

Approximately seven months.

1.4 Setting (formal / informal learning)

The setting is mainly formal and follows the inquiry-based learning methodology but can also be informal (e.g. participation in science fairs and festivals, virtual visits to CERN and interaction with relevant scientists).

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** Primary school teachers cooperate and share ideas, activities and experiences. Students are engaged in several activities, work together and cooperate with other schools.
- **Arts-based:** The design and implementation of activities enhances the interconnection of science with the creative and artistic expression of children. Students design and form models and come up with their stories to express their ideas.
- **Dialogic space/argumentation:** Students are engaged in argumentation and dialogic processes through inquiriy-based learning and storytelling.

- **Visits to research centres (virtual/physical):** Students make use of CERN virtual tours and the sites of CERN experiments.

- **Communication of scientific ideas to audience:** Students externalize the scientific concepts they have acquired while interacting with other schools and present their work in science fair festivals. Furthermore, storytelling improves their writing skills and their self-engagement to ensure scientific consistency and verification.

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2. Rational of the Activity / Educational Approach

2.1 Challenge

Students read on the news that a curious ferret shut down the largest and most powerful particle accelerator on the planet when chewed a power cable. Following the ferret's life inside CERN, they discover how CERN scientists work, the subatomic world and the recent discoveries in the area of particle physics and cosmology.

This demonstrator addresses the need to introduce younger audiences to the world of particle physics and cosmology in an easy and accessible way by nurturing and promoting their creativity and their STEM skills.

2.2 Added Value

Young children hold their own theories about the world around them when coming to school. The role for the primary teacher is to organize the child's first ideas into coherent concepts which are both accurate and explicit (Pine, Messer & John, 2001). On the other hand, there is a growing understanding and recognition of the power of children's early thinking and learning as well as a belief that science may be a particularly important domain in early childhood. Early science learning will not only help students to build a basis for future scientific understanding but also to develop important skills and attitudes for learning (Duschl, Schweingruber, & Shouse, 2007 ● Eshach & Fried, 2005 ● Watters, Diezmann, Grieshaber, & Davis, 2000).

Furthermore, research has shown that early exposure to STEM initiatives and activities has a positive effect on elementary students' perceptions and dispositions (Bagiati, Yoon, Evangelou, & Ngambeki, 2010). By capturing students' interest in STEM content at an early age, a proactive approach can ensure that students are on track through middle and high school to get engaged effectively with science and technology.

This demonstrator describes a structure for learning through three basic ideas:

1. Doing science is a natural and critical part of children's early learning
2. Children's curiosity is the foundation for beginning to use skills of inquiry to explore scientific concepts
3. The early science exploration can be used to develop other important skills, including working with one another, project completion, algorithmic thinking, storytelling, and presentation skills.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of teaching intervention include a basic understanding of the following:

- The scientific way of thinking
- Particle Physics
    - All matter in the Universe is made of very small particles
    - What the characteristics and properties of particles are
    - How particles interact to create new particles
    - How scientists detect them
- The role of CERN in understanding the fundamental structure of the universe
    - How the Large Hadron Collider (LHC) accelerates particles to reach very high energy
    - How physicists use particle collisions to understand the fundamental structure of matter and the forces that are responsible for its behaviour
    - How particle detectors work
    - The role of CERN in the investigation and discovery of the Higgs boson
- The Earth and the Universe
    - Earth is a very small part of a solar system with our sun in its center that in turn is a very small part of the universe
    - The Big Bang theory
    - The evolution of the Universe

3.2 General skills objectives

The main student skills' objectives are:

- To develop creative and critical thinking skills
- To develop problem-solving and STEM skills while generating and implementing practical solutions to challenges
- To develop language skills by transforming their engagement into creative activities and storytelling
- To use model making and playing games to help access and understand scientific ideas
- To acquire scientific inquiry skills
- To connect science with aspects of everyday life
- To work effectively with other students of the same or other schools around common goals and shared tasks
- To acquire presentation skills to communicate their ideas

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to introduce students to the concepts of science, particle physics and cosmology in a creative, playful and interdisciplinary way. Through experimentation, model making, game playing, artistic expression and storytelling the demonstrator also aims to stimulate students' curiosity about physics and related subjects such as cosmology and to help them understand the process of scientific inquiry.

4.2 Student needs addressed

Activities were chosen in such a way that, based on childrens' inherent curiosity about the structure of the universe, to build and enhance their learning of scientific concepts. Having students motivated by and engaged in authentic and real problems that require solving in the area of particle physics and related domains, the designed activities aim to stimulate their creativity and critical thinking and make them key players in the learning process. The students are engaged in applying creative solutions while dealing with topics through inquiry-based learning processes. Furthermore, the aim of the program "Adventures of a ferret at CERN" (AF@C) is to develop the metacognitive skills of students through writing development activities and storytelling.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics, Physics, Astrophysics, Cosmology, History of Science, Engineering, Technology, Computer Programming **Relevance to national curriculum:** It can act as a valuable scaffold for standard in-class activities related to the teaching of science at senior primary school level. **Class information** **Year Group:** Senior primary school **Age range:** 10 -12 **Sex:** both **Pupil Ability:** Mixed (The scenario allows space for pupils of various abilities to participate)	**Materials and Resources** **What do you need? (eg.printed questionnaires, teleconference, etc.)** Introductory PowerPoint and Powtoon presentations on particle physics, CERN etc. Simple everyday (i.e. kitchen physics) materials Teacher guidelines **Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?** School classroom Science laboratory Computer laboratory **Health and Safety implications:** None **Technology:** Hardware: Computers with internet access, tablets with internet access, projector, Arduino kits Software: Office suite (e.g. MS Office), Video editing software (e.g. Movie Maker), Augmented reality software (e.g. Aurasma), Scratch, Scratch4Arduino

	Teacher support: Preparation, support and scaffolding

Prior pupil knowledge

While no prior knowledge of physics is required, a prior knowledge of basic features and statements of Scratch programming language is welcome.

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***

Session 1: Introduction to CERN and acquaintance with the main hero of storytelling

In this session students are attracted to get familiar with the place where the hero of their storytelling lives. They learn where CERN is located, why was established and the kind of research that is carried out. They also learn about Large Hadron Collider (LHC), the main experiments and the important scientific discoveries made at CERN.

Session 2: Introduction to the scientific thinking and the scientific method

In this session students are attracted to get engaged with the method that scientists work. They understand that scientists generate scientific theories based on evidence, but they do not always find definitive answers. They also learn that observation, discussion, negotiation, teamwork and communication are key features of the scientific knowledge.

Session 3: Introduction to the structure of matter and the elementary particles

In this session students are engaged with the structure of matter. They learn about the basic constituents of matter, their structure and their differences. They also learn about the Standard Model of particle physics and the fundamental forces in the universe.

Session 4: Introduction to accelerators and detectors at CERN

In this session students are attracted to engage with the way CERN' s accelerators and detectors work. They learn how particles are accelerated at the LHC and the way they are detected. They also learn how scientist analyze the scientific data that are retrieved from the LHC experiments.

Session 5: Introduction to Cosmology

In this session students are attracted to engage with the big bang theory. They learn about the age of the universe and the prevailing cosmological model from the earliest known periods through its subsequent large-scale evolution.

Session 6: (Self)creating, exploiting and disseminating

This session uses the knowledge and works created by students in previous sessions to produce an augmented reality board that could be used as an exploration board about CERN. The challenge for students is to create an information center that could be used by anyone who would like to learn about CERN. The augmented reality board will also be used to present CERN to other schools or in science fair festivals.

Follow up activity in every session

As a metacognitive activity following each every session, students produce a written account of their hero in a diary, a story that emerged from the session they have participated in. In this way, they construct the knowledge and an overall understanding of what they have acquired during every session, by interpreting them into a storytelling activity.

Assessment	**Differentiation**	**Key Concepts and Terminology**

Teachers use mainly formative assessment for improving student understanding and performance in every activity. Students are engaged in inter-workgroup assessment processes. They define the assessment criteria that act as activator of reflection processes, engaging members of the same group to strengthen their arguments.	*How can the activities be adapted to the needs of individual pupils?* The AF@C approach is grounded on the belief of showing respect to students' needs and interests which represent a cornerstone for its successful realisation.	**Science terminology:** CERN, particle physics, scientific method, matter, antimatter, molecules, atoms, protons, neutrons, electrons, leptons, quarks, bosons, Higgs boson, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, solar system. **Arts terminology:** Video, augmented reality board and model making, drawing, comic, storytelling

Session Objectives:

During this scenario, students will deepen their understanding of the scientific method, particle physics and cosmology. They will also effectively use their creativity, ICT and storytelling skills to express their new knowledge.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONS Features	Student	Teacher	Potential arts activity
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Balance and navigation through dialogue aids teachers and students in creatively navigating educational tensions, including	Students' interest is stimulated by small videos starring a ferret which through its mischief presents the subject under study. They are encouraged to	Teacher attracts the student's interest by small videos starring a curious ferret that shut down the LHC chewed a power cable. Through its mischief, teacher presents the subject under study and guide students to	None at this stage.

	between open and structured approaches to IBSE. Questions may arise through dialogue between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through dialogue with different ways of knowledge inspired by interdisciplinarity and personal, embodied learning. Ethics and trusteeship is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	formulate questions and familiarize themselves with the problem at hand.	investigate a scientifically oriented question. E.g. the ferret's and its friends' mischief to hide in a CERN tour and to be in front of the bottle of hydrogen gas, can lead to a journey into the structure of matter. In this phase teacher asks students challenging questions related to each video and initiate a discussion in order to familiarize them with the topic.	
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from individual, collaborative and communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. Risk, immersion and play is crucial in empowering pupils to generate, question and discuss evidence.	Students work in groups and explore with the help of the teacher simple ways in which they can plan and conduct simple investigation. They are also engaged in several experiments and activities in order to explore different answers following observation and interpretation.	Teacher uses challenging questions and follow up tasks on students' work in order to identify possible misconceptions and provide the appropriate guidance.	Students create models, drawings and comics using their imagination and creativity.

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Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using dialogue with each other and the teacher to support their developing understanding.	Students analyse the practical work done. They perform, show, illustrate the work done in the practical session. Analyse difference among work groups, and identify strong points and weaknesses.	Teacher acts as facilitator/contributor of the process.	None at this stage.
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider possibilities for explanations that are original to them. They use argumentation and dialogue to decide on the relative merits of the explanations they formulate, playing with ideas.	Students explain and re-elaborate what they worked on considering also other outcomes.	Teacher acts as facilitator/contributor of the process.	None at this stage.
Phase 5	Students connect their explanations with scientific knowledge, using	Students connect what learned to their own	Teacher acts as a facilitator/contributor in the process	Storytelling

CONNECT: students connect explanations to scientific knowledge	different ways of thinking and knowing ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	experience, knowledge, and reality. They also connect the acquired knowledge with the ferret's diary.	and enhances the connectivity with other disciplines	
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of possibilities, ideas and justifications through dialogue with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be immersed in a key part of the scientific process. Such communication is crucial to an ethical approach to working scientifically.	Students are invited to present to their school classmates and to those of other schools their creations, observations and justifications. They are also invited to present their work to scientists of CERN (through videoconference) and in science fair festivals.	Teacher acts as facilitator/contributor of the process.	Presentations, drawings, augmented reality board.

Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are stimulated into discussing and reflecting back at the end of each practical session and at the end of all sessions. They are also asked to evaluate the process and learning experience.	Teacher initiates the evaluation through dialogue and collects and acts on feedback.	None at this stage.

6. Additional Information

Additional information and resources about AF@C can be found at:

- The Adventures of a ferret Playing with Protons at CERN
  A blog that contains the activities of AF@C.
- PwP Crete online community
  The CREATIONS community by primary school teachers of Crete of the "Playing with Protons" programme.

Additional information about the "Playing with Protons" programme can be found at:

- Playing with Protons
  The website of the "Playing with Protons" programme.
- PwP Greece online community
  The CREATIONS community by Greek primary school teachers of the "Playing with Protons" programme.
- Science Experiments for Kids
  A blog created by Tina Nantsou (Pedagogical responsible for the "Playing with Protons" programme).

7. Assessment

Teachers use mainly formative assessment for improving student understanding and performance in every activity. Short term gained knowledge is assessed at the end of workshops through questions and students' presentations.

Students are also engaged in inter-workgroup assessment processes. They define the assessment criteria that act as an activator of reflection processes, engaging members of the same group to strengthen their arguments.

Long-term gained knowledge will be assessed through long term collaboration with specific teachers and schools.

Evaluation of the activity will also be completed using the evaluation procedures decided by the CREATIONS project team under work package 6.

8. Possible Extension

The AF@C activities are designed for students at the age group of 10 to 12 years old. However, as described at section 2.2, learning science should begin early in every child's schooling. Thus, a possible extension would be to redesign the activities of AF@C demonstrator for a younger age group of 6 to 9 years old.

Another extension of great beneficial educational outcome would be to extend the SP's activities involving the engagement and exchange of pedagogical ideas and alternative solutions among teachers on Crete. This way, more schools and students will have the opportunity to acquire a first-hand experience of AF@C activities.

9. References

Bagiati, A., Yoon, S., Evangelou, D., Ngambeki, I. (2010) Engineering Curricula in Early Education: Describing the Landscape of Open Resources. *Early Childhood Research & Practice 12* (2).

Duschl, R., A., Schweingruber, H., A., & Shouse, A., W. (Eds.). (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington, DC: National Academies Press.

Eshach, H., & Fried M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology, 14* (3), 315-336.

Pine, K., Messer, D. & John, K. (2001). Children's Misconceptions in Primary Science: a survey of teachers' views. *Research in Science & Technological Education, 19* (1), 79-96.

Watters, J. J., Diezmann, C. M., Grieshaber, S. J., & Davis, J. M. (2000). Enhancing science education for young children: A contemporary initiative. *Australian Journal of Early Childhood, 26* (2), 1-7.

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D3.2. 11. 5I&3D in PWP: A science education that has meaning and significance for pupils' lives

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Paris Papadopoulos
Code:	D 3.2. 11	**Contributors:**	
Version & Date:	**V 3.0**	**Approved by:**	**NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Particle Physics, Astronomy, Cosmology, History and Philosophy of science, scientific literacy

1.2 Type of Activity

Local in-school activities companied with some field trips to science parks

1.3 Duration

Concerning in-school activities, Playing with Protons is deemed appropriate to have at a minimum 35 didactic hours devoted to up to five subjects. Concerning out-of-school activities, one or two field trips to research infrastructures, science museums etc. year are needed.

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science fair) and engages multiple actors including students, teachers, scientists and parents.

1.5 Effective Learning Environment

- **Experimentation (Science laboratories and Science applications): Hands on applications-** Pupils form teams and watch, participate and reproduce or design experiments.
- **Inquiry team learning through Jigsaw strategy:** Via e-phet simulations, books (The universe in your hands: Christophe Galfard-George's Secret Key to the Universe: Stephen Hawking, Lucy Hawking,Galileo by Bertolt Brechtand videos.
- **Visits to research centers (virtual/physical):** children make use of CERN virtual tours to explore the Lhc, Alice, Cms and Atlas CERN experiment sites. Pupils visit NOESIS technological museum and attend the scientific projects: From earth to the Universe , Dream Big – engineering miracles and The exhibition: Nikola Tesla the man who invented the future
- **Art-based workshops, learning by doing:** Pupils reproduce, design and express their aesthetic concepts and ideas using every day materials to form items about Cern, Universe, technology, atoms and the microcosm.
- **Creative writing and story-telling in science.**
- **Transformative learning** through "art" a case application: Galileo, Brecht and Science for citizenship education.
- **Role-Plays, argumentation and debate:** Role playing, argumentation and debating offer opportunities to express views or discuss controversial issues and set the background for pupils to discuss on, the way scientific ideas change through time and interact with the social and cultural context that supports them.

2. Rational of the Activity / Educational Approach

2.1 Challenge

Our starting point has been a review on the suggested aims of teaching in the scientific literacy context. Researchers point out that scientific literacy for all involves goals related to personal growth, professional development and citizenship (Bybee, 1997). Additionally, scientific literacy aims to the development of target-skills concerning the capacity to use scientific knowledge, to identify questions and to draw evidence-based conclusions in order to understand and help make decisions about the natural world and changes made to it through human activity (Kjærnsli, 2009). Nevertheless, the adoption of scientific literacy educational objectives entails consequences for the content, organization and pedagogy of school science education that could be characterized as profound and radical (Jenkins, 1990). In this approach pupils besides learning science contents, need to become acquainted with and have an appreciation for the nature of science (Matthews, 1994).

Scientific literacy may become the essential baggage for understanding the world in a society with such an increasing scientific and technological development. Scientific literate citizens are to make informed choices about their health care, the environment and the society they live in. They need to develop skills for critically analyzing the validity of given arguments presented in the media or in public discussions as well as for coming to logical conclusions and decision-making based on scientific information rather than on propaganda or bias.

2.2 Added Value

In teaching science one of the most difficult task is that the instructor, must confront the obstacle of motivating pupils to take an active interest in abstract and complex 'theoretical' issues. All too often the pupils find the various science concepts especially those about microcosm covered in such a course, to be 'too difficult' and, in their eyes, 'un-motivating' (especially when compared with, e.g., an ethics or aesthetics course). Scientific literacy can be viewed as multidimensional and a synthesis of various scientific aspects: concepts and ideas, the nature of science, the interaction of science and society (Bybee, 1997,1999; Fensham, 2002; Hurd,1997; Laugksch, 2000; Solomon, 2001; Millar, 1983). Researchers believe that in school we could tempt pupils into a lifelong interest in science through exciting and contentious new phenomena, such as Particle Physics, Astrophysics, Cosmology, and History of science,Genetic engineering, Climate change, Brain and memory, or the origin of life in space (Solomon & Thomas, 1999; Tsarsiotou & Seroglou, 2011; Seroglou et al, 2011).

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3. Learning Objectives

In our *5I & 3D in PWP: A science education that has meaning and significance for pupils' lives* educational project that was attended by 5th and 6th grade students of elementary school our main learning objective in science teaching is to provide pupils with the necessary scientific "baggage" so as to be competent enough to participate in role-plays that engage them into argumentation and debate. Debate in science is a product of the use of drama and simulations in vivo. Since it involves children in physical and intellectual activities, it has a potential to elucidate scientific concepts (McSharry & Jones, 2000). It can also be defined as a way of deliberately constructing an approximation of aspects of a 'real life' episode or experience, but under 'controlled' conditions (Kofoed, 2006). Involving non-players in socio-dramatic play seems to provide them with an adaptable medium for constructing meaningful connections among the many information fragments they are daily bombarded with. It provokes the formation of meaningful associations between new experiences and prior adaption (Dansky, 1980).

In controlled studies measuring the use of drama in teaching science, greater meaningful learning occurred when drama has been used (Metalcafe, 1984). Debate lies in another tradition entirely: the humanities. We understand as teachers that the arts (music, movement, art drama) have great potential to contribute to learning across the curriculum (Koster, 2001). Especially in physics debate, makes a valuable contribution to pupils' understanding of the nature of science. In particular, there is a significant move away from the serendipitous empiricism and towards an appreciation of the interactive nature of experiment and theory. It may provide a widening experience for pupils to capture the whole picture of science and also encourage the development of skills and attitudes in the context of teaching science for citizenship and scientific literacy. Nevertheless, debate through role-play provides a cultural bridge between the two 'worlds', inside and outside of the school, forboth pupils and teachers (Seroglou, 2006; Papadopoulos & Seroglou, 2007; Papadopoulos & Seroglou, 2009).

The theory behind the use of debate in science teaching and learning - as with 'active', 'experiential' or 'child-centered' learning - is that children are encouraged to be physically and intellectually involved in the classroom to allow them to both express them-selves in a scientific context and develop an understanding of difficult concepts (Taylor, 1987). The key to debating through role-play, and the reason why role-play can help to make science relevant to many children, is that it is based upon 'playing'. By the time that children begin to be educated in science, they are already very experienced at playing, since they practice playing during their childhood. The desire to play, and therefore to learn, is a fundamental part of human psychology and is a potentially powerful resource residing in the children themselves (Piaget, 1951). Debate in this context is a kind of *simulation* or moral/ethical role-play and has to do with simulated meetings, simulated speeches and life conditions or human relationships (McSharry, et al., 2000). It can provide pupils with opportunities to explore a range of ideas other than their own and also introduce them to a variety of values and interpretations concerning the nature of science. When it is used for teaching science can be a stage for the formation of skills such as the ability of realizing social, ethical or political situations through a variety of different points of view (Seroglou, 2006; Bentley, 2000).Role-playing in science makes science teaching vivid and understandable. During this verbal negotiation process, children become aware of many aspects of the story, aspects other than their own. In order to engage in play, children have to accommodate their views to the views of others. One has to understand the character's (performed) point of view in order to act convincingly. Defining the boundaries between the performer and the character, the performer is forced into a meta-cognitive process and becomes a spect-actor being at the same time both the spectator

of a story and the actor in the role-play (Boal, 2006). Debating creates contexts in which pupils can simulate situations from outside the classroom bridging practical knowledge with theoretical knowledge. It allows children to rehearse and develop skills they will need for active citizenship, in a safe and non-threatening situation (Seroglou 2006, Papadopoulos & Seroglou, 2011). Skills as effective communication and use of language in role-play, work beyond the nominal and descriptive, and require the application of higher order skills, such as synthesizing ideas in order to question, explain, reason, justify, form and express opinions. Social skills such as working collaboratively, sharing, listening and responding, compromising and reaching decisions are necessary for successful interaction during the discussions that were evolved during the debate. In our case, pupils learn some concepts better as they study them through controversial situations. A large part of this improvement has undoubtedly been due to 'innovation enthusiasm' and innovative active learning.

In other words, any strategy that extends the sort time spam of the pupils' attention is likely to improve learning, whether or not includes drama practices. Using debate as a teaching method leads to better test scores, longer sustainability, increased pupil motivation and an augmented pupils' appreciation that their work has been meaningful. Pupils appear more attentive and provide verbal and written responses that indicate greater interest in the teaching content and a better understanding of science concepts (Papadopoulos, 2010). These new skills and attitudes related to teaching and learning science in the context of scientific literacy need to be classified and evaluated through new analysis frameworks that may record and interpret such data.

3.1 Domain specific objectives

In order to specify our domain specific objectives a three dimensional cognitive, metacognitive and emotional framework (Seroglou & Koumaras, 2001; Seroglou, 2006) has been used coupled with the theory of multiple intelligence (Bosniadou, 2001; Coleman 1995, 2006; Gardner 1983, 1993, 1994, 1997, 1999; Guss 2005; Koster, 2001; Warrington, &Younger, 2006). According to the three dimensional framework of teaching and learning science (3D framework), we approach science teaching through three complementary dimensions:

a) **The cognitive dimension** dealing with pupils' involvement in learning science, problem-solving skills, content management in verbal negotiation and learning and thinking through observation and experiment.

b) **The meta-cognitive dimension** concerning meta-cognitive skills activated when students' reconsider the current interrelations of science and society, reflect on the nature of science aspects (such as history and philosophy of science, methods of science, evolution of scientific theories, ethics concerning science, science-society historical interactions). Furthermore, skills concerning argumentation and causality styles are also included in this meta-cognitive dimension.

c) **The emotional dimension** reflecting the way pupils explore attitudes and values, their interest and motivation, the positive classroom climate and the feeling that their work is meaningful. (Table 1.)

The 3D framework of teaching and learning science	
Cognitive Dimension	involvement in learning
	problem solving

	content management	
	learning and thinking through observation & experiment	
Metacognitive Dimension	reconsidering the interrelations of science and society	
	reflecting on nature of science considering its'	history
		method
		historic evolution
		ethic
		philosophy
	argumentation	
	causality	
Emotional Dimension	exploring attitudes and values others than their own	
	increased interest and motivation	
	positive classroom climate	
	feeling that their work is meaningful	

Table 1. Classification of skills and attitudes concerning the 3D framework of teaching and learning science

According to the five intelligences framework of teaching and learning science (5I framework), we approach science teaching through five faculties of intelligence coming from Gardner's theory of multiple intelligences:

a) **Verbal-linguistic intelligence** referring to the abilities of pupils to use narrative comprehension and narrative production to express oneself rhetorically and scientifically, to express through writing without the need of adult support, to get familiar with and use unfamiliar scientific vocabulary and to remember and use scientific information in their speech.

b) Intrapersonal intelligence focusing on pupils' capacity to express their feelings, to strengthen their self-awareness and self-esteem, to increase their self-control, to make decisions and become more independent. The above include appreciating one's feelings, fears, motivations, values and ideas, acquiring an effective working model of one self and being able to use such information to regulate one's life.

c) Interpersonal intelligence dealing with communicational and interactive skills, the capacity to understand the intentions, motivations and desires of others when co-operating with them, the un-biased interaction with others and cooperatively learning in groups or with only one partner.

d) **Bodily kinesthetic intelligence** revealing the potential of using body-gesture symbols and activating mental abilities to coordinate bodily movements, the involvement of acting and imitating skills when reproducing science related scenes in detail.

e) **Visual-spatial intelligence** concerning the ability of room-orientation, the engagement of creative fantasy, skills of mental perception and representation. Recording the ways that students learn visually and organize things spatially (e.g. do, enjoy charts, graphs, maps, tables, illustrations, art, anything eye catching) (table 2).

The multiple intelligences framework of teaching and learning science	
Linguistic Intelligence	increased narrative comprehension and production
	decreasing need for adult support during writing
	use of unfamiliar (scientific) vocabulary
	greater knowledge retaining
Intrapersonal Intelligence	expression of feelings
	self-esteem and self-awareness
	self-control
	decision making
	increasing independence
Interpersonal intelligence	social and communication skills
	sharing and working together in groups
	acceptance of difference
	participation through peer-group

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Bodily-kinesthetic intelligence	using body-gesture symbols
	acting skills
	ability to observe carefully and then recreate scenes in detail (imitate)
Spatial intelligence	sense of room-orientation
	creative fantasy
	mental perception and representation

Table 2. Classification of skills and attitudes concerning the multiple intelligences framework 5I of teaching and learning science.

3.2 General skills objectives

In the context of the 5I & 3D in PWP, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art (students will create a multi-disciplinary artistic performance -Science Theater- which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- Develop spirit of cooperation and teamwork

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

- Nowadays, our students in Greek Elementary School, are educated and trained in the traditional science education context but on the other hand they are asked to study, learn and live in the current scientific literacy trend. At the same time the current word wide scientific literacy view, differs from what we teach in our elementary science classrooms to our pupils. That means that they have to go through a shift from the traditional to the scientific literacy for all style of learning and additionally this should be within the context of new science subjects that deal with matters of science edge. In this science classroom we should apply a numerus of changes in approaching the various science concepts so as to achieve scientific literacy. Our main aim is to provide our students of 6^{th} grade of elementary school with the efficient knowledge and information about quantic physics so as to increase their motivation and interest about them in order eventually to be able to participate in role-plays that include argumentation and debate about matters that deal with basic science dilemmas, concepts and views. This can be achieved by:
- *Multidimensional activities* and a synthesis of various scientific aspects: concepts and ideas, the nature of science and the interaction of science and society
- *Educational activities based on creativity-enriched inquiry-based approaches (school based).*
- *Educational activities that promote school-research center collaboration.*
- *Alternative and dynamic didactic methods*, providing art-informed teaching strategies such as debate and argumentation via role-plays

4.2 Student needs addressed

Our pupils demand a science education that has meaning and significance for their lives. They want to address science issues they hear about through media, and get a bigger picture of how scientific concepts fit together in the overall scheme of today's world: to see more of the building, in short, and less of the bricks. Pupils want greater autonomy and creativity in learning, including more practical work, more extended investigations and more opportunities to express views or discuss controversial issues. New methodological approaches should be used in order to achieve teaching science for all. The target skills developed in school need to be reassessed, as do the ways in which pupils are expected to learn. One obvious method of overcoming this dilemma is to provide science issues such as PWP through alternative and dynamic didactic methods, providing art-informed teaching strategies such as role-play practices, which are definitely less complicated than general descriptions of theories, articulate the main points (meta-cognitive, nature of science) more clearly, and have the added bonus of being more 'personal' and relatable. Role-play activities in PWP can serve to involve and motivate students to develop an understanding of the world that is rooted in the scientific and humanistic traditions in keeping with a more integrated, holistic view of knowledge. It helps pupils formulate ideas and stimulate debate, by offering useful opportunities for speculation and hypothesis. These role-plays can both illustrate the scientists' or non-experts' ideas, but also raise the students' interests in and enjoyment of the teaching content. They provide a dynamic environment for studying scientific concepts and bringing forward the elements and questions that pupils face in their everyday life inside or outside school. So debate through role-play has much to contribute to the composing life of the primary school, while as a teaching instrument is a holistic methodology that

creates the experiential and social educational experiences that Dewey advocates (Dewey, 1934, 1997) and which also appeals to the variable learning styles and multiple intelligences that Howard Gardner promotes (Gardner, 1983; 1994; 1997; 1999). Besides, theatrical language is considered as the most essential human language, a form of knowledge and most of all, a medium for change and a mean of giving pupils the strength and confidence to overcome their learning difficulties (Boal, 2007).

5. Learning Activities & Effective Learning Environments

Science topic: Physics, Particle Physics, Astronomy, Cosmology, History and Philosophy of science, Scientific literacy. Grades 5 and 6 _ Science Education Class information Year Group: 5-6 Age range: 9-12 Sex: both Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) all inclusive NOTE: Children of younger ages can be involved in the activities in a playful way and with an emphasis on artistic creations.	***What do you need? (e.g.* printed questionnaires, teleconference, etc.)** • Simple household materials for conducting "*kitchen physics*" experiments. • Introductory power point presentations on particle physics, CERN etc. • Videos of Cern and the projects than are undertaken there (LHC, ATLAS, CMS, ALICE). • Videos of Phet's experiment Simulations • Videos of Galileo from the series "The six experiments that changed the world" • Science books:The universe in your hands: *Christophe Galfard*, George's Secret Key to the Universe: *Stephen Hawking*, Lucy Hawking, Galileo by *Bertolt Brecht* • Simple materials for drawing, model making, game playing • Various props for theatrical acts • Leaflets as guide about the role-plays of debate and argumentation. ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?*** - School classroom or science lab - School theatre or room that can facilitate lecture and group work **Health and Safety implications?** None **Technology?** Computers with internet access, projector for power point presentations **Teacher support?** Preparation, support and scaffolding

Prior pupil knowledge

Elementary pupils cannot instantly be taught about particle physics, the microcosm and the experiments and projects that are undertaken in Cern. This should be done gradually as though especially in Greek elementary curriculum students aren't taught any physic conceptions until 5th Grade. So in the year that for the very first time they communicate and learn about science we are going to apply our *PWP project*.

Individual session project objectives

Our starting point is to create a scientific context for students that will provide them the various scientific concepts as a series from the weather phenomena to the particle physics, from the macrocosm to the microcosm.

Session Objectives:

During this scenario, students will:

Session 1: Weather phenomena (5 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation and another 1 didactic hour should be devoted to creative writing)

- Which are the weather phenomena?
- The circle of water
- How can we predict the weather phenomena?
- Why people need the prediction of the weather phenomena?
- Were there any myths and misconceptions about the weather phenomena?
- How has our knowledge changed during time about the weather phenomena?
- What do we know about the sun?
- What's the true profound meaning about Prometheus ancient Greek myth?

Session 2: Cosmology (10 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation and another 1 didactic hour should be devoted to creative writing)

By the end of this session, students are expected to understand:

- What is the Universe made of?
- How does the Universe evolve?
- Why is the Universe so big and old?
- How do we know the age of the Universe?
- How does light travel across the Universe and why does it appear in our eyes in various colors?
- How many dimensions does the Universe have?
- How do galaxies move within the Universe?
- What scientific experiments are currently carried out to help us understand better what is the Universe made of?
- What did people believe about the Universe in the past and what changes in our Knowledge and new inventions helped them to form new ideas?
- Which was the role of Romeo Catholic Church against the new scientific notions about Universe in the medieval period?
- How our Knowledge about Universe affected the interrelations of science and society in the domains of: Ethics, Philosophy and historic evolution.

Session 3: Elementary Particles (5 didactic hours; at least 2 didactic hour should be devoted to hands-on experimentation)

By the end of this session, students are expected to understand:

- What are the basic constituents of matter?
- What is the structure of the atom?
- How small is the atom and its basic constituents?
- Who were the scientists who discovered the atom and its basic constituents?
- What are the fundamental forces in nature by which matter is effected?
- What is the Standard Model in particle physics?
- How do particles acquire their mass?
- How can scientists at CERN discover new particles?
- What did Philosophers and scientists believed about atoms in the ancient Greece?
- How our Knowledge about atoms does affects our culture?

Session 4: An Introduction to CERN: Past, Present and Future (5 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)

By the end of this session, students are expected to understand:

- When, how and why was CERN established?
- What kind of research is carried out at CERN?
- How many countries do take part in CERN's experiments?
- What's the role of Greece in Cern?

- Why are there so many physicists and engineers at CERN? Are there other professions involved in CERN?
- What is the Large Hadron Collider?
- What are the main LHC experiments and what do they study?
- What are the important scientific discoveries made at CERN?
- What does the future behold for the experiments at CERN?

Session 5: Accelerators and Detectors at CERN and their Technological Applications (5 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)

By the end of this session, students are expected to understand:

- How does a particle accelerator work?
- How many particle accelerators do exist at CERN and what are the main differences between them?
- Why do scientists smash protons with each other at the LHC?
- How do scientists detect the results of particle collisions at the LHC?
- What are the main components of a particle detector and why are particle detectors at CERN so big?
- Why are the LHC and the particle detectors built underground?
- What kind of scientific data do scientists retrieve from the LHC experiments and how do they perform their analyses?
- In what ways do the experiments at CERN benefit our everyday life?
- What are the most important technological applications of CERN for society?

Session 6:
Transformative learning through art-Role-plays: Debate & argumentation (5 didactic hours)

This session builds on the knowledge that students have acquired in the previous 5 sessions and gives them opportunities to evolve the Metacognitive Dimension of learning in science reconsidering the interrelations of science and society and reflecting on nature of science considering its' history, method, historic evolution, ethic and philosophy. Our aim is to develop contemplative mood and to evolve an appropriate teaching tool-method that offers critical approach to learning issues, utilizing the aesthetic experience. The application that was implemented during Flexible Zone in sixth grade of elementary school in order to teach the particle physics science topics, indicates and highlights the multiple learning possibilities offered by the didactic development and application of arts in classroom.Theatre has much to contribute to the composing life of the primary school. Theatre techniques may provide a widening experience for pupils to see the whole picture of science and also encourage the development of skills and attitudes in the context of teaching science for citizenship and scientific literacy. Nevertheless, theatre techniques provide a cultural bridge between the two 'worlds', inside and outside of the school, for both pupils and teachers (Seroglou, 2006, Papadopoulos & Seroglou 2007).Our main intention is the evolvement of communication skills, which would allow students to participate in public debates and argumentations. We use a great variety of theatre techniques, such as, role play, debate, expert's robe and imaginary trials.

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Evaluation (Initial, Mid-term, Final) by the teacher in the form of questionnaires, students' workbooks, diaries and presentations.	*How can the activities be adapted to the needs of individual pupils?* "5I & 3D in PWP: A science education that has meaning and significance for pupils lives"activities are customized to the students' learning needs according to their age, gender, skills and abilities.	**Science terminology:** weather, phenomena, circle of water, atoms, protons, neutrons, electrons, quarks, bosons, Higgs particle, CERN, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, electromagnetism, nuclear force, Web. **Arts terminology:** collage, tableau, drawing, comics, model making, theatrical performance, role plays, debate, argumentation, imaginary trials, creative writing and story-telling in science

Session 1: Weather phenomena

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore weather phenomena.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in weather phenomena.	**Pantomime** depicting the circle of water.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.			None at this stage

Phase 3: **ANALYSE:** students analyze evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.			None at this stage
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.		None at this stage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.		.	None at this stage
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			Role-plays

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			**Creative-writing and story-telling in science:** Pupils work in teams and create their own stories, poets, acronyms and enigmas about weather phenomena.

Session 2: Cosmology				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore the Universe.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in **Cosmology**.	**Pantomime** depicting the solar system.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual*, *collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.			None at this stage
Phase 3: **ANALYSE:** students analyze evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.			None at this stage
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.			None at this stage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			**Constructions** and draws of the solar system
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with			Role-plays

COMMUNICATE: students communicate and justify explanation	professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual*, *collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			**Creative writing and story-telling in science:** Pupils work in teams and create their own stories, poets, acronyms and enigmas about cosmology
Session 3: Elementary Particles				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1:	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue*	Eg. Engage with teacher's questions.	Eg. Will use challenging	**Pantomime** depicting the

QUESTION: students investigate a scientifically oriented question	aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Watch videos and use the web to explore atoms.	questions and the web (images, videos) to attract the students' interest in **Elementary Particles.**	atoms of Oxygen, Hydrogen etc.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.			None at this stage
Phase 3: **ANALYSE:** students analyze evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.			None at this stage
Phase 4:	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.			None at this stage

EXPLAIN: students formulate an explanation based on evidence				
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			**Constructions** of elementary particles
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			**Creative writing and story-telling in science:** Pupils work in teams and create their own stories,

				poets, acronyms and enigmas about elementary particles.

Session 4: An Introduction to CERN: Past, Present and Future				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore Cern constructions and history.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in **Cern's presence**.	**Role-plays:** pupils form teams of scientists of the various countries that are Cern's members and inform each other for their contribution to Cern.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual*, *collaborative* and *communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk*, *immersion* and *play* is crucial in *empowering* pupils to generate, question and discuss evidence.			None at this stage
Phase 3: **ANALYSE:** students analyze evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.			None at this stage
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.			None at this stage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			None at this stage
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual*, *collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			None at this stage

Session 5: Accelerators and Detectors at CERN and their Technological Applications				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore Accelerators and Detectors at CERN and their Technological Applications.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in Accelerators and Detectors at CERN and their Technological Applications.	None at this stage

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.			None at this stage
Phase 3: **ANALYSE:** students analyze evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.			None at this stage
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.			None at this stage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			Constructing models of Accelerators and Detectors at CERN

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			

6. Additional Information

The "*5I & 3D in Playing with Protons: A science education that has meaning and significance for pupils' lives"* educational initiative was introduced to the 3rd Primary School of Lagadas and the 5th Primary School of Kilkis during sthe chool year 2017-2018.

Picture 1: Demonstrations and experiments about weather phenomena –The macrocosm

Picture 2: Demonstrations and experiments about the light and the rainbow –The macrocosm

Picture 3: Demonstrations and experiments about the light and the sunset–The macrocosm

Picture 4: Demonstrations and experiments about the light and the sky–The macrocosm

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Picture 5: Evolving students' imagination and observation skills and abilities: Tell us the story behind the footprint

Picture 6: Evolving students' imagination and observation skills and abilities- Which cup get filled firstly?

Picture 7: 5th Elementary School of Kilkis- Atom models

https://gnomikilkis.blogspot.gr/2017/11/5-project-cern.html

Picture 8: 3rdElementary School of Lagadas- Atom mode

Picture 9: Time bends

https://www.youtube.com/watch?v=r2hcPOVeiqs

Picture 10: Sketching the time bending

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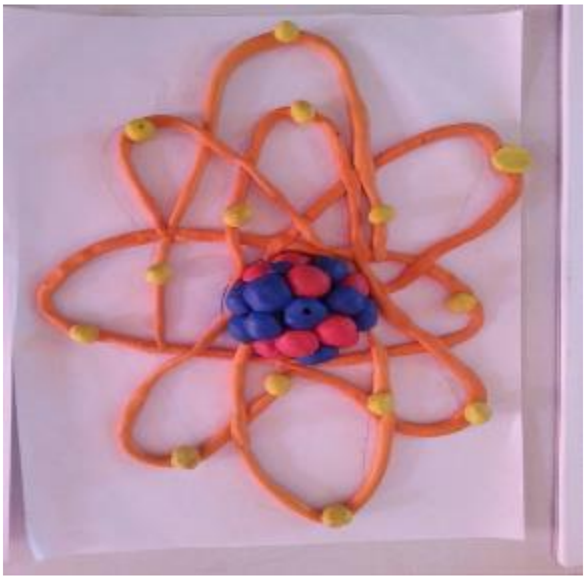

Picture 11: Atom models -3rd Experimental Elementary School of Eyosmos

Picture 12: The Big Bang- 3rd Elementary School of Lagadas

Picture 13: The Big Bang -3rd Experimental Elementary School of Eyosmos

Picture 14: The solar system

Picture 15: Drawing the ATLAS Detector

Picture 16: Creating the Globe of Science and Innovation

Picture 17:Visits to technological exhibitions - Planetarium

7. Assessment

The demonstrator has been evaluated quantitatively by both students and teachers in accordance with CREATIONS assessment protocol that requires the pre- and post-intervention use of the SMQ II questionnaire for students and the VALNET (plus open questions) questionnaire for teachers. More details on the above tools can be found in Deliverable D6.2.

Specifically:

- 122 pupils of grades 5 and 6 participated in the pre-intervention stage and completed the online questionnaire.
- Short term gained knowledge has been assessed at the end of each session through engineering artifacts, questions and the student presentations.

The evaluation of the activity will be completed in May 2018 when the 122 pupils will complete the post-intervention online questionnaire. Finally, the teachers involved in the activity will complete the VALNET questionnaire.

8. Possible Extension

The demonstrator can be fruitfully extended to include role-playing and debate in physics and more widely in science learning through which students can develop and apply their argumentation and debate skills in a primary science education context.

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D3.2.12. Playing with Protons

Project Reference:	H2020-SEAC-2014-1 , 665917	**Authors:** Angelos Alexopoulos, Tina Nantsou	
Code:	D3.2.12	**Contributors:**	
Version & Date:	v1.0, 11 Feb 2017	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics, Astrophysics, Cosmology, History of Science, Engineering, Technology

1.2 Type of Activity

Playing with Protons focuses mainly on in-school activities but can also include out-of-school activities such as field trips to research infrastructures, science parks and science museums, and participation in science fairs.

1.3 Duration

Concerning in-school activities, Playing with Protons is deemed appropriate to have at a minimum 20 didactic hours devoted to up to five subjects. Concerning out-of-school activities, one or two field trips to research infrastructures, science museums etc. per school year are recommended.

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science fair) and engages multiple actors including students, teachers, scientists, parents and the local community.

1.5 Effective Learning Environment

- Communities of practice
- Dialogic space / argumentation
- Experimentation (Hands-on, Science laboratories and eScience applications)
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

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2.1 Challenge

Empirical research suggests that students' aspirations of pursuing a career in STEM fields, including physics, are likely to be shaped considerably by their experiences of and attitudes to school science at primary level (e.g. Tai et al., 2006). Yet the majority of interventions currently target secondary school settings (Archer, 2013). In response to this shortcoming, *Playing with Protons* (PwP*)* represents a novel science education initiative led by the CMS Experiment at CERN that is aimed at nurturing and promoting creativity, science motivation and aspirations among K-6 students. PwP comprises continuous professional development (CPD) courses for primary teachers, development of learning resources and communities of interest, and follow-up support in schools and especially those that serve students from remote or relatively disadvantaged communities. The focus in this document will be on PwP activities in schools.

2.2 Added Value

There is widespread consensus among science education researchers that learning science should begin early in every child's schooling. Among many good reasons, one stands out clearly: "Children naturally enjoy observing and thinking about nature" (Eshach & Fried, 2005). Several studies have also shown that the public wants science to be taught early. For example, in a recent public opinion survey conducted for the *Center for the Future of Teaching and Learning at WestEd*, seven in ten Californians expressed the view that learning science in primary school is likely to increase the chances of students to perform well in high school (Belden, Lien & Nelson-Dusek, 2010). In line with the above, several initiatives to engage primary school students have taken place in collaboration with CERN. These include the *Mains dans la pate* initiative of Georges Charpak in France, the *Dans la peau d'un chercheur* project that reaches out to K-6 students from CERN's neighboring schools in Switzerland and France, and the *Enthusing Future Physicists* project in the UK that is run by the School of Physics and Astronomy at the University of Birmingham (Pavlidou & Lazzeroni, 2016).

PwP contributes to that effort by enriching teachers' pedagogical practice with creative, hands-on methodologies through which K-6 students can, in turn, get engaged effectively with science, technology and innovation. PwP was born out of the passion, dynamism and determination of Tina Nantsou, a physics educator at Hill Memorial School in Athens, Greece. In 2013, Nantsou visited CERN as a participant in the Greek Teacher Programme, and upon her return to Athens started a still ongoing project in collaboration with CERN that involves 10 to 12 year old students at her school. Accordingly, the students become familiar with big ideas and latest discoveries in particle physics mainly through hands-on experimentation with everyday materials. The educational approach promotes inquiry, creativity and collaborative learning (Alexopoulos, 2014).

3. Learning Objectives

The learning objectives of PwP stem from the six assertions made by Eshach & Fried (2005) with regard to the idea that even small children should be exposed to the world of science. These assertions are:

1. Children naturally enjoy observing and thinking about nature.
2. Exposing students to science develops positive attitudes towards science.
3. Early exposure to scientific phenomena leads to better understanding of the scientific concepts studied later in a formal way.

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4. The use of scientifically informed language at an early age influences the eventual development of scientific concepts.
5. Children can understand scientific concepts and reason scientifically.
6. Science is an efficient means for developing scientific thinking.

3.1 Domain specific objectives

The learning objectives of PwP focus mainly on the domain of particle physics, but may well extend to astrophysics and cosmology. In addition, students are familiarized with basic aspects of engineering, technology and history of science that are related to research in particle physics, astrophysics and cosmology. In particular, by the end of the programme, the students are expected to have a basic understanding that:

- All matter is made of the same constituents, that is, elementary particles which compose larger particles, for example protons, neutrons and eventually atoms
- There are four fundamental forces or interactions in nature (i.e. gravitation, electromagnetic, weak nuclear force, strong nuclear force) by which matter is effected
- Elementary particles are too small to be seen by the naked eye or an average microscope, but particle physicists have invented over the last century more and more advanced ways of detecting them
- Scientists and engineers at CERN have built the Large Hadron Collider (LHC) that is currently the world's most powerful microscope, enabling them to collide particles with each other in order to understand the inner structure of matter but also to discover new particles
- The universe is, to a very large extent, filled in with dark matter and dark energy about which scientists until now know very little
- The study of particles is also a long story of scientific creativity, innovative thinking, international collaboration and technological development
- The study of particles has and will continue to benefit many aspects of our everyday life mainly through the transfer of technological know-how to medicine, communication, transport and other industries.

3.2 General skills objectives

PwP places explicit emphasis on the development of the following general skills among K-6 students:

- *Collaboration*. The students are divided into workgroups (four to six students per group) and embark on their educational journey to the world of particle physics by developing a group identity around common goals and shared tasks to be performed throughout the duration of the programme
- *Problem-solving.* Through hands-on experimentation with everyday materials, the students define a challenge (e.g. design and assemble an electrical circuit to be used for a particle accelerator mock-up), generate alternative solutions, evaluate their pros and cons, and finally implement and follow up on their solution
- *Creativity.* Through hands-on experimentation with everyday materials, the students are invited to think originally and imaginatively by employing their intuition, sensory abilities and language skills in the course of creative activities such as drawing and designing, storytelling, model making, gamifying and theatrical acting

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- *Dealing with mistakes.* The students are encouraged to consider mistakes as part of any process and work including the scientific work. The students realize through their involvement with hands-on experimentation that trial and error is inherent in problem solving. Emphasis is thus given on the process and not the end result.
- *Communication and presentation*. Each workgroup is invited to keep a diary in which the students document each phase of their assigned projects along with their thoughts, impressions and challenges they are faced with. Each group is also asked to present their progress to the rest of the class on a monthly basis. Finally, upon the completion of their projects, all groups present their work and answer questions by the teacher and their classmates.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Beyond creating interest in the world of particle physics, astrophysics and cosmology, PwP lays the foundation for effective student engagement through in-class but also out-of-class learning-by-doing activities that employ hands-on experimentation with everyday materials, game playing, model making and artistic expression of scientific phenomena, ideas, stories and achievements. In doing so, PwP aspires to enhance and enrich the primary science curriculum and the thrill of learning science for 5^{th} and 6^{th} graders.

To date, PwP activities have been implemented in 17 primary schools in Greece with the active participation of 32 teachers and 896 K-6 students.

4.2 Student needs addressed

PwP rests on the idea that learning science can be a self-fulfilling activity that may create strong personal interest in and engagement with big ideas in particle physics and related domains. PwP provides an opportunity for students to use their imaginative thinking to co-create new ideas, concepts and forms that train their minds and hands simultaneously. At the same time, PwP activities are structured around the CREATIONS features, the RRI aspects and the IBSE features. In addition, PwP activities allow space for pupils of various abilities to participate and contribute their distinctive skills. Importantly, PwP promotes diversity and attempts to break gender stereotypes about the role of women in science and technology.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics, Physics, Astrophysics, Cosmology, Engineering, Technology **Relevance to national curriculum:** PwP activities can act as valuable scaffolds for standard in-class activities related to the teaching of science at senior primary school level. **Class information** **Year Group:** Senior primary school **Age range:** 10-12 **Sex:** Both **Pupil Ability:** Mixed (The scenario allows space for pupils of various abilities to participate)	**Materials and Resources** ***What do you need? (e.g.* printed questionnaires, teleconference, etc.)** - Simple household materials for conducting "*kitchen physics*" experiments - Introductory power point presentations on particle physics, CERN etc. - Simple materials for drawing, model making, game playing - Various props for theatrical acts ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?*** - School classroom or science lab - School theatre or room that can facilitate lecture and group work **Health and Safety implications?** None **Technology?** Computers with internet access, projector for power point presentations **Teacher support?** Preparation, support and scaffolding
Prior pupil knowledge While no prior knowledge of particle physics is required, a preparatory session initiated by the science teacher is welcomed. In this session, the teacher is advised to ignite students' curiosity by showing relevant material or inviting students to do so at home. The material may be in electronic or print format and should provided to the students in advance. The ultimate aim is to initiate the inquiry cycle by posing a "big question" or discovery in particle physics, astrophysics or cosmology that will then be followed up by the students through hands-on experimentation in class.	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** During this scenario, students will: **Session 1: Cosmology (4 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)** By the end of this session, students are expected to understand: • What is the Universe made of? • How does the Universe evolve?	

- Why is the Universe so big and old?
- How do we know the age of the Universe?
- How does light travel across the Universe and why does it appear in our eyes in various colours?
- How many dimensions does the Universe have?
- How do galaxies move within the Universe?
- Who were the first scientists who helped us understand how and why the Universe expands?
- What scientific experiments are currently carried out to help us understand better what is the Universe made of?

Session 2: Elementary Particles (4 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)
By the end of this session, students are expected to understand:

- What are the basic constituents of matter?
- What is the structure of the atom?
- How small is the atom and its basic constituents?
- Who were the scientists who discovered the atom and its basic constituents?
- What is the difference between hadrons and leptons?
- What are the fundamental forces in nature by which matter is effected?
- What is the Standard Model in particle physics?
- How do particles acquire their mass?
- How can scientists at CERN discover new particles?

Session 3: An Introduction to CERN: Past, Present and Future (4 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)
By the end of this session, students are expected to understand:

- What does the acronym CERN stand for?
- When, how and why was CERN established?
- What kind of research is carried out at CERN?
- How many countries do take part in CERN's experiments?
- Why are there so many physicists and engineers at CERN? Are there other professions involved in CERN?
- What is the Large Hadron Collider?

- What are the main LHC experiments and what do they study?
- What are the important scientific discoveries made at CERN?
- What does the future behold for the experiments at CERN?

Session 4: Accelerators and Detectors at CERN and their Technological Applications (4 didactic hours; at least 1 didactic hour should be devoted to hands-on experimentation)
By the end of this session, students are expected to understand:

- How does a particle accelerator work?
- How many particle accelerators do exist at CERN and what are the main differences between them?
- Why do scientists smash protons with each other at the LHC?
- How do scientists detect the results of particle collisions at the LHC?
- What are the main components of a particle detector and why are particle detectors at CERN so big?
- Why are the LHC and the particle detectors built underground?
- What kind of scientific data do scientists retrieve from the LHC experiments and how do they perform their analyses?
- In what ways do the experiments at CERN benefit our everyday life?
- What are the most important technological applications of CERN for society?

Session 5: Creativity Zone (4 didactic hours)
This session builds on the knowledge that students have acquired in the previous 4 sessions. During the "creativity zone" session, the students work in groups, each of which selects a topic of interest (e.g. particle detectors). The challenge for students is to demonstrate and communicate in hands-on and creative ways, through model making, play gaming, drawings, music, dance performances or sketches, their understanding, knowledge and interpretation of the scientific phenomena, ideas and discoveries that were introduced to them during the previous four sessions.

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Evaluation (quantitative & qualitative) by the teacher in the form of questionnaires, students' workbooks, diaries and presentations	*How can the activities be adapted to the needs of individual pupils?* PwP activities are customized to the students' learning needs according to their age, gender, skills and abilities	**Science terminology:** atoms, protons, neutrons, electrons, quarks, bosons, Higgs particle, CERN, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, electromagnetism, nuclear force, Web **Arts terminology:** collage, tableau, drawing, comics, model making, theatrical performance, stand-up comedy, dance, music

Session Objectives:
During this scenario, students will:
- engage with big questions driving scientific research in particle physics, physics, astrophysics and cosmology.
- learn about the science, engineering , technology and history that are related to particle physics, physics and astrophysics experiments
- embark on hands-on learning experiences with simple, everyday materials
- embark on model making and game playing
- embark on artistic activities such as drawing, comic making, stand-up comedy, dance and theatrical performances

Learning activities in terms of CREATIONS Approach

NOTE: Selected examples from the aforementioned sessions are included herein

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in	Students engage with teacher's questions and demonstrations, and are encouraged to formulate questions relative to the topics of interest (e.g. how do galaxies move within the universe?)	Teacher attracts the interest of students by utilising appealing visuals of: - a rotating galaxy (session 1) - the inner structure of the atom or the "Scale of the Universe" video (session 2)	None at this stage.

	experimental design and collaborative work, as well as in the initial choice of question.		- an aerial view or a close up of the LHC (session 3) - e.g. the CMS detector (session 4) Teacher also asks students challenging questions related to each of those images or videos	
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students work in groups and explore with the help of the teacher simple ways in which they can describe or reenact a natural phenomenon (e.g. expansion of the universe with the use of a balloon, collision of particles with the use laser beams and flour, blue sky / red sunset experiment)	Teacher follows up on students' questions and provides guidance concerning sources of evidence that can help students examine in a playful manner a natural phenomenon under question (e.g. expansion of the universe, collision of particles, why the sky is blue/red etc.)	Students engage in creative hands-on experimentation that may also entail arts activity (e.g. dance performance inspired by the rotation of galaxies or by the collision of particles at the LHC)

Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use trial and error to determine the conditions under which they can simulate e.g. a sunset	Teacher invites students to try out different techniques related to e.g. Rayleigh scattering	None at this stage.
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students embark on particle model making, game playing and theatrical re-enacting in order to explain a scientific phenomenon or discovery	Teacher facilitates and supports as required	Students employ their imagination and creativity in designing and building particle detector models or performing a sketch.
Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students are invited to discuss their explanations with their parents and out-of-school friends in an effort to make meaningful connections with their social environment outside the school.	Teacher facilitates and supports as required.	None at this stage.

Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are invited to present to their classmates but also to scientists (through videoconference or in-situ) their creations, observations and justifications.	Teacher facilitates and supports as required.	Plenty of room for arts based activities including sketches, stand-up comedy, dance and music performances.
Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the newly acquired knowledge at the end of the fifth session as well as to evaluate the process and learning experience	Teacher collects and analyses feedback from students and uses this to inform a continuous cycle of quality improvement that enhances the student's experience with the demonstrator.	None at this stage.

6. Additional Information

More information on PwP activities, teaching resources, school initiatives, ideas and more on primary science education can be found at:

- PwP Greece online community (the CREATIONS community by Greek primary school teachers of the PwP programme at CERN)
- Science Experiments for Kids (a blog by physics educator Tina Nantsou)

Also available:

- Two articles on the CERN website about the PwP initiative in Greece
    - Playing with protons in primary
    - CERN inspires primary-school students to Play with Protons
- A documentary charting the progress of the project in Hill Memorial School
- Two articles about the related PwP CPD course that took place at CERN in August 2016 with the participation of ten primary school teachers from Greece
    - Playing with protons: Engaging teachers to engage K-6 students with science, technology and innovation
    - Greek teachers learn ABCs of particle physics at CERN

7. Assessment

The overall assessment of the PwP demonstrator follows the procedure as presrcibed by the CREATIONS evaluation team. Specifically, two instruments are employed for the assessment of students and teachers respectively. First, students are assessed longitudinaly (i.e. before and after their involvement with PwP activities) in terms of their science motivation and creativity by completing questionnaire surveys. Second, t eachers assess various aspects of the demonstrator after its implementation with the use of a short questionnaire based on the VALNET evaluation framework.

In addition to the CREATIONS evaluation procedure, PwP activities may be evaluated qualitatitavely by the teacher after the completion of the various sessions through examination of the students' diaries and presentations as well as through questions in order for the teacher to verify whether students have understood or misunderstood key scientific concepts.

8. Possible Extension

As mentioned in Section 2.1, a core aspect of PwP is the provision of CPD courses for primary school teachers. The courses, which are organized by the CMS Experiment at CERN in the framework of the CREATIONS project, bring together teachers, CERN researchers and science education specialists to develop creative approaches for engaging K-6 students with science, technology and innovation.

The 1st PwP CPD course for primary school teachers from Greece took place at CERN from 17 to 22 August 2016. The course included lectures by CERN and other scientists, hands-on workshops, visits to experimental facilities, study groups and Q&A sessions. More info on that course can be found here. A new course for UK primary school teachers will take place again at CERN in August 2017. This is organized in collaboration with CREATIONS partners from the University of Birmingham and STFC and will be supported by the Ogden Trust.

Greek primary school teachers during a hands-on workshop at CERN in August 2016

(Image: Sophia Bennett/CERN © CERN)

9. References

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D3.2.13 Icarian cosmonauts travelling in science.

Project Reference: H2020-SEAC-2014-1, 665917		**Authors:** Tsigkrelis Kostas
Code: D.3.2.13.		**Contributors:**
Version & Date:	23 May 2018	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Cosmology, Gravity, Astronomy, CERN

1.2 Type of Activity

Indoor and outdoor activities within the school premises.

1.3 Duration

30 didactic hours devoted to up to five subjects.

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science fair) and engages multiple actors including students, teachers, scientists, parents and the local community.

1.5 Effective Learning Environment

- Arts based:

  The children used several materials and made hands-on constructions, such as particles.

- Dialogic space / argumentation

  Argumentation took place among groups. The groups discussed about what they were going to make, the methodology they used to make it and how they would present it.

- Experimentation (Hands-on, Science laboratories)

  The children experimented in the various domains of the program in groups constructing and making lab experiments.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

The main focus of the program was to promote dialogue techniques among the pupils and enhance the collaboration within teams so as for them to communicate effectively, make decisions, find ways to complete tasks and present them to others.

This particular approach was selected because this group of pupils showed great difficulty in cooperating with others, reaching to conclusions and accepting other ideas.

2.2 Added Value

The educational approach adopted for this program was Constructivism. Children were urged to express their ideas about the scientific issues of the program. Then they compared and contrasted their own ideas with the outcomes of the experimentation on the scientific issues presented. Whenever their ideas were different from the outcomes, there was cognitive conflict; their existing knowledge was revised and new knowledge was reconstructed based on the outcomes.

The whole process adopted the notion of "hands on learning" because it combines theory with acting. That is, Art with Science. Only this way, constructivism theory becomes effective.

3. Learning Objectives

3.1 Domain specific objectives

The learning objectives were:

- Exposing pupils to activities relevant to science in order for them to develop a positive attitude towards science in general.
- Having pupils acquainted with scientific phenomena in order for them to better understand scientific issues that will study later on.
- Familiarize pupils with the processes of scientific thought and knowledge.
- Seeking answers to questions relevant to Science, Astronomy and Cosmology.
- Acquiring knowledge through experiments relevant to Science, Astronomy and Cosmology.
- Dealing with learning activities and experiments using simple everyday material.
- Involving pupils to dealing with science relevant issues.
- Promoting skills such as cooperation, communication, creativity development and involvement in theatrical and playful activities.
- Bring schools closer to local community.
- Engage parents and the general public into schools' actions.

3.2 General skills objectives

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop spirit of collaboration and teamwork
- Connect the science classroom with parents and local communities

4. Demonstrator characteristics and Needs of Students

4.1Aim of the demonstrator

The demonstrator's main aim was the students to get acquainted with the particles, cosmology, gravity, astronomy and CERN. The "Icarian Cosmonauts" were supposed to get in touch with the corresponding concepts of Physics by carrying out scientific experiments using simple materials, become familiar with the scientific terms, cultivate scientific thinking and investigate answers to questions about science.

The project addressed 16 students of the 5th grade and 12 of the 6th grade of Agios Kirikos 2nd Primary School in Icaria.

4.2Student needs addressed

This particular course on Science was created in order to intrigue students into thinking differently when it comes to Science. More particularly, the students were asked to express their own ideas about Science based on their personal experiences. After that, judging from the outcomes of the experiments done in class they were asked either to verify their beliefs, or question them. This way, cognitive conflict occurred and students were asked to adopt the scientific truth. Another important aspect of the program is to hopefully create Science thinkers that would be willing to convey their acquired knowledge to others. For example, they could give their family or peers the scientific explanation of why the sky is blue.

5. Learning Activities & Effective Learning Environments

Science topic: particles, cosmology, gravity, astronomy and CERN. **Relevance to national curriculum:** The topics of the course were in accordance with the curriculum of Science teaching at primary school. **Class information** **Year Group:** Primary school **Age range:** 10-12 **Sex:** Both **Pupil Ability:** Mixed (The scenario allows space for pupils of various abilities to participate)	**Materials and Resources** ***What do you need? (e.g.* printed questionnaires, teleconference, etc.)** - Everyday materials for experiments - Power point presentations and videos about the parts of program ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?*** - School classroom - Schoolyard **Health and Safety implications?** None **Technology?** • Computer with internet access • Projector **Teacher support?** - Preparation - Support - Scaffolding
Prior pupil knowledge The personal ideas of students about the parts of program	

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***

During this scenario, students will:

Session 1: Elementary Particles (8 didactic hours)
By the end of this session, students are expected to understand:

- What are the basic constituents of matter?
- Which is atom's structure?
- What is the Standard Model in particle physics?
- Who were the scientists who discovered the atom and its basic constituents?
- How small the atom and its basic constituents is?
- How particles acquire their mass?

Session 2: Cosmology (8 didactic hours)
By the end of this session, students are expected to understand:

- What is "the Big Bang"?
- What is "Hubble's Law"?
- What is the Universe made of?
- Why is the Universe so big and old?
- How do we know the age of the Universe?
- How do galaxies move within the Universe?
- Who were the first scientists who helped us understand how and why the Universe expands?
- What scientific experiments are currently carried out to help us understand better what the Universe is made of?

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Session 3: Astronomy (5 didactic hours)
By the end of this session, students are expected to understand:

- What is the light?
- Why does the sky get those particular colors during sunrise and sunset?
- What is the spectrum?

Session 4: Gravity (5 didactic hours)
By the end of this session, students are expected to understand:

- What is gravity?
- What does the free falling of objects depend on?
- What is the Theory of Relativity?
- Why do the astronauts hover when they are in space?

Session 5: Acquaintance with CERN (4 didactic hours)
By the end of this session, students are expected to understand:

- What does CERN stand for?
- When, why and for what reason was CERN founded?
- What kind of research is made in CERN?
- Why are there so many scientists in CERN?
- What is the Large Hadron Collider?
- How do the CERN experiments affect everyday life?
- What are the important scientific discoveries made in CERN?

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Evaluation (quantitative & qualitative) by the teacher in the form of questionnaires and students' stem constructions and presentations	*How can the activities be adapted to the needs of individual pupils?* PwP activities are customized to the students' learning needs according to their age, gender, skills and abilities	Cosmology, Particles, Gravity, Astronomy, CERN **Science terminology:** atoms, protons, neutrons, electrons, quarks, bosons, Higgs particle, CERN, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, nuclear force, Web, gravity, spectrum, light wave length.

Session Objectives:
During this scenario, students will:
-cultivate scientific thinking and rationale
-get accustomed to using the official scientific terminology
-engage with big questions driving scientific research in particle physics, astrophysics, gravity and cosmology.
- embark on hands-on learning experiences with simple, everyday materials
- embark on model making and game playing

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in	Students are activated by the teacher's questions and demonstrations and are encouraged to formulate their own questions relative to the topics of interest (e.g. what are the quarks?)	Teacher attracts the interest of students by using challenging questions and the web (images, videos) to attract the students' interest in the parts of the program (cosmology, astronomy, gravity, particles and CERN)	None at this stage.

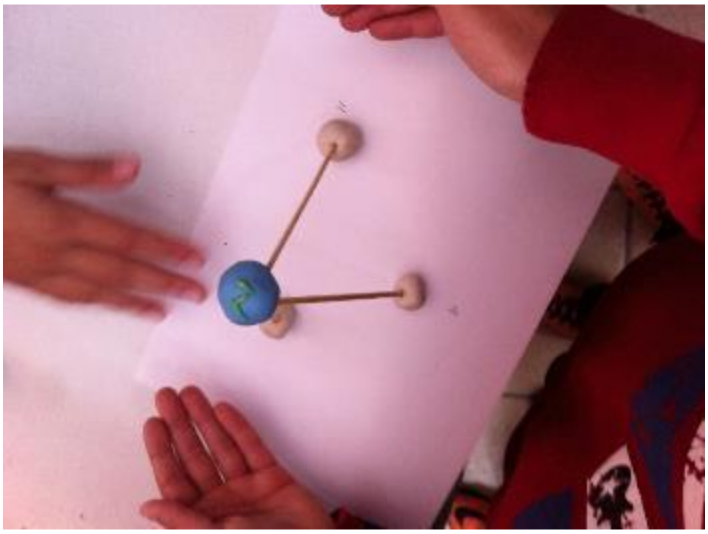
	experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students work in groups and explore with the help of the teacher simple ways through which they can describe or reenact a natural phenomenon (e.g. expansion of the universe with the use of a balloon, collision of particles with the use of laser beams and flour, blue sky / red sunset experiment)	Teacher follows up on students' questions and provides guidance concerning sources of evidence that can help students examine, in a playful manner, a natural phenomenon under question (e.g. expansion of the universe, collision of particles, why the sky is blue/red etc.)	Students engage in creative hands-on experiments that may also entail artistic activity (e.g. dance performance inspired by the movement of the atom's structural elements or by the collision of particles at the LHC)
Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use experimentation in groups, analyse the evidence collected, choose the most important and present them to the rest of the groups.	Teacher invites the groups of students to compare the evidence among them.	None at this stage.

Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students create particle models, a model of the universe expanding, the structure of the atom and of the molecule in order to explain a scientific phenomenon or a discovery.	Teacher facilitates and supports as required	Students employ their imagination and creativity in designing and building models or performing a sketch.
Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students are invited to make some experiments out of the school and discuss their conclusions with their parents and friends in an effort to make meaningful connections with their social environment outside the school.	Teacher facilitates and supports as required.	None at this stage.
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process.	Students are invited to present their creations, observations and justifications to their classmates and proceed to their evaluation.	Teacher facilitates and supports as required.	Arts based activities can accompany the presentation.

	Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are invited to evaluate the process and the learning experience and state what the most pleasant and the least pleasant part of the course was.	Teacher collects and analyses feedback from students and uses this to improve the whole course.	None at this stage.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

6. Additional Information



7. Assessment

Students filled in a questionnaire before the beginning of the course through which they expressed their opinion and feelings towards Science. The same questionnaire was completed once again after the course has finished. The results showed that students gained a more positive attitude towards Science, they better understood natural phenomena and they did not consider Science as something farfetched.

Moreover, an assessment questionnaire of the course was completed by the teacher of the course in order for him to evaluate the implementation of the objectives.

Also, during the course the groups of students evaluated their actions and creations at the end of each session.

8. Possible Extension

An idea of a possible extension is that the students during the summer celebration at the end of the school year could present some basic parts of the program to the audience and present them with their construction

9. References

- The experiments of the course were based on the brochures of Tina Nantsou, which were distributed in CERN during the summer course "Playing with protons" for Greek teachers.

D3.2.14. Playing with Physics

Project Reference: H2020-SEAC-2014-1, 665917	**Authors: Yiorgos Patsoulakis**
Code: D.3.2.14.	**Contributors:**
Version & Date: V1 , 22 May 2018	**Approved by:NKUA**

1. ntroduction/ Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics, Astrophysics, Cosmology, History of Science, Engineering, Technology, Art and Physics

1.2 Type of Activity

Playing with Protons shows the magic dimension of the word "playing" as an important effort to strengthen the positive sciences and especially physics in primary school.

We try to create interesting activities for the students based on school physics, but also to energize their imagination and their creativity.

1.3 Duration

31 didactic hours**,** 21 of them devoted to hands on experimentation.

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science fair) and engages multiple actors including students, teachers, scientists, parents and the local community.

1.5 Effective Learning Environment

- **Communities of practice (virtual-physical)** The students separated in five work teams have the opportunity to come in contact with creative activities , discovering the right function of a structure , making their owns models and test them .
- **Arts-based**: the design and implementation of engineering plans involves children's artistic self-expression as well
- **Dialogic space / argumentation:** Anything that happens in to the classroom and of course in to the work-teams, it is a product of partners dialogue , discussion, agreements and disagreements with a real result based and calculate a lot of opinions.
- **Experimentation (Hands-on, Science laboratories and eScience applications):** Sometimes the class give the impression of a magic laboratory . Young scientists, without lifting their head over their creations discuss, wonder , find , testing ! Beyond physical experimentation , children have the opportunity with the help of computers and projectors to see simulations and digital models of some experiments that can't be done into the classroom.
- **Visits to research centres (virtual/physical)** : One of the best ways for learning is the visits to research and educational centers . Children are impressed of the knowledge that these centers give them(Greek Planetarium, Stavros Niarchos Foundation etc) . Knowledge which goes with the physic presence of special scientists . Virtual visits at CERN and their accelerators, colliders etc., also have their frequently place in to our lesson .
- **Communication of scientific ideas to audience:** Students at the end of the school year, will present their work, their art, their handicrafts, their experiments etc to a physic festival in our school which will last for an all day. This festival will be open for other students, parents, teachers and people of our city. The presentation will be in science and thematic stations. Astronomy, cosmology, particle physics, creativity, gravity will be some of them, with the opportunity of the audience to take part in all of them.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

How easy or difficult is to speak and teach for particles the students to a primary school ,especially in a poor neighborhood ? What could be done for the success of a try like this? How can I find the time to teach all these new things in to a curriculum which is not flexible? Will be easy or hard to convince the parents about the significance of this program?

Not one but many challenges. Through the duration of this program I saw that this challenges can be overcome.

Excitement, originality, creativity and science are the best aids. Also the results of many educational researches proves that actions like these needs to begin at primary school. Age of 14 years old is too late.

But most of all is the conviction that a well prepared teacher can teach everything!

2.2 Added Value

There is big gain with the application of our program "Playing with protons" at the primary school. It's the confirmation of the educational theories that the students can create positive attitudes for the sciences when the motivations and the teaching ways are interesting and well designed .

If you consider that the scientific and research potential in Europe gets poorer as the time pass , the need to make young people love science , it's a big matter.

The biggest value for the program is the children to strengthen their self-confidence and to believe that they can succeed in an area that often scares them.

This can be done more easily than we imagine.

For the beginning : "Children naturally enjoy observing and thinking about nature" (Eshach & Fried ,2005) We have in our side the child nature.

That was the reason that I choose for our first activity to go with my students to our school garden for smell , touch and feel!

3. Learning Objectives

3.1 Domain specific objectives

The main learning objectives that we study in our project were:

- To feel the way within we try to solve a problem. Investigate models.
- To learn that the matter around us is made by molecules. Difference between elements and chemical compounds.
- Understanding that molecules are made from atoms. Get knowing protons , neutrons, electrons. Moves in an atom.
- Cosmology: the big bang theory and how all got start .
- Cosmos expands . Hubble's law.
- Astronomy: Gravity and the curvature of space-time. How can we see it?
- The sun and his colours.
- CERN and particles. Explaining with simp le way what CERN make for us. Why is the most perfect microscope and the time machine which travel us from the big bang to today.
- How the detectors of CERN works in a simple way and what they looking for.
- A few words for Higs boson . Easy examples how the matter got mass.

3.2 General skills objectives

The program places explicit emphasis on the development of the following general skills of our students:

- ***Collaboration.*** 26 students (10 years old) are divided in workgroups (4 groups of 5 children and one group with 6 children). Our target is to cooperate and produce a team result. We encourage the weak students to involve and we don't accuse the wrong answers. We talk about them and make believe that the mistake will lead us to the right.
- **Creativity**: We encourage the innovating thoughts and solutions. We try to apply them and construct different models that explain our subject. We see prototype things that make us enthusiastic. Creativity it is not only for handicrafts and experiments, but also for art, dance, drama activities etc.
- ***Communication and presentation***. The time that every team will present it's work is one of the most exciting moments in to the classroom. It's so special seeing students teaching and speaking with enthusiasm for their products.
- ***Art and drama***. Some activities have the opportunity to represented with move, dramatization , songs . I believe that these activities relax children and make them more positive for physics. Also they live it with their imagination as they were inside , let's say for example ,to a detector.
- ***Happiness and positive feelings:*** We need happy children in our schools, so the education will be more effectively and will last longer. Every student who is happy in his school will learn better and will be socialized easier. This can be happen easier with interesting activities.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator helps , especially the teachers, to organize and describe with specific way a project. In our program it's very important this because we talk about a special section of physics , as particles, who needs simple and stable steps to get forward.

4.2 Student needs addressed

Everything that I lived in CERN made me to realize the size and the significance of the cooperation. People from over the world , men and women, had equal participation for the same target. This is something that I want to transfer to my students through our activities. I believe that this project it's most of all an attitude for life, who our students will meet as adults.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics, Physics, Astrophysics, Cosmology, Engineering, Technology **Relevance to national curriculum:** PwP activities can act as valuable scaffolds for standard in-class activities related to the teaching of science at senior primary school level. **Class information** **Year Group:** Senior primary school **Age range:** 10-11 **Sex:** Both **Pupil Ability:** Mixed (The scenario allows space for pupils of various abilities to participate)	**Materials and Resources** ***What do you need? (e.g.* printed questionnaires, teleconference, etc.)** - Simple household materials for conducting experiments - Introductory power point presentations on particle physics, CERN etc. - Simple materials for drawing, model making, game playing - Various props for theatrical acts ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?*** - School classroom - School room that can facilitate lecture and group work - School yard -School garden **Health and Safety implications?** None **Technology?** Computers with internet access, projector for power point presentations **Teacher support?** Preparation, support and encouraging.
Prior pupil knowledge A lesson to our school garden, looking the nature, speaking for the matter and it's components. The children make their own molecules with plasticine and straws.	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** During this scenario, students will: **Session 1: Elementary particles 6 didactic hours. 4 of them devoted to hands on experimentation.** By the end of this session, students are expected to understand:	

- What are the basic constituents of matter?
- What is the structure of the atom?
- How small is the atom and its basic constituents?
- Who were the scientists who discovered the atom and its basic constituents?
- What are the fundamental forces in nature by which matter is effected?
- How do particles acquire their mass?
- How can scientists at CERN discover new particles?

Session 2: Cosmology 6 didactic hours. 4 of them devoted to hands on experimentation.
By the end of this session, students are expected to understand:

- What is the Universe made of?
- How does the Universe evolve?
- Why is the Universe so big and old?
- How do we know the age of the Universe?
- How does light travel across the Universe and why does it appear in our eyes in various colours?
- How many dimensions does the Universe have?
- How do galaxies move within the Universe?
- Who were the first scientists who helped us understand how and why the Universe expands?
- What scientific experiments are currently carried out to help us understand better what is the Universe made of?

Session 3 Astronomy and gravity 7 didactic hours. 4 of them devoted to hands on experimentation.
By the end of this session, students are expected to understand:

- What we know about light?
- Why the sky has these colours at the middle of the day and at the sunset?
- How the light travels?
- What Einstein says with his theory of relativity?
- Why the planets , the galaxies , the meteors moving with this way?

- Why earth makes elliptical orbit around the sun?

Session 4: Introduction to CERN. Accelerators and Detectors at CERN and their Technological Applications 6 didactic hours. 3 of them devoted to hands on experimentation.

By the end of this session, students are expected to understand:

- What does the acronym CERN stand for?
- When, how and why was CERN established?
- What kind of research is carried out at CERN?
- How many countries do take part in CERN's experiments?
- Why are there so many physicists and engineers at CERN? Are there other professions involved in CERN?
- What is the Large Hadron Collider?
- What are the main LHC experiments and what do they study?
- What are the important scientific discoveries made at CERN?
- What does the future behold for the experiments at CERN?
- How does a particle accelerator work?
- Why do scientists smash protons with each other at the LHC?
- How do scientists detect the results of particle collisions at the LHC?
- What are the main components of a particle detector and why are particle detectors at CERN so big?
- What kind of scientific data do scientists retrieve from the LHC experiments and how do they perform their analyses?
- In what ways do the experiments at CERN benefit our everyday life?
- What are the most important technological applications of CERN for society?

Session 5: Creativity Zone 6 didactic hours , all of them devoted to hands on experimentation.

This session builds on the knowledge that students have acquired in the previous 4 sessions. During the "creativity zone" session, the students work in groups, each of which selects a topic of interest (e.g. particle detectors) with the main target to be the model construction of CERN.The challenge for students is to demonstrate and communicate in hands-on and creative ways, through model making, drawings, their understanding, knowledge and interpretation of the scientific phenomena, ideas and discoveries that were introduced to them during the previous four sessions.

In our case students decided to build at the school yard their own CERN.

Also they made their own spacecrafts guided by Mrs Efi Tavlariou , professor of arts in our school.

Assessment	Differentiation	Key Concepts and Terminology
- Evaluation (quantitative & qualitative) by the teacher in the form of questionnaires, students' workbooks, diaries and presentations	*How can the activities be adapted to the needs of individual pupils?* PwP activities are customized to the students' learning needs according to their age, gender, skills and abilities	**Science terminology:** atoms, protons, neutrons, electrons, quarks, bosons, Higgs particle, CERN, LHC, particle accelerators, particle detectors, Big Bang, galaxies, dark matter, dark energy, electromagnetism, nuclear force, Web **Arts terminology:** collage, tableau, drawing, comics, model making, theatrical performance, stand-up comedy, dance, music

Session Objectives:
During this scenario, students will:
- engage with big questions driving scientific research in particle physics, physics, astrophysics and cosmology.
- learn about the science, engineering , technology and history that are related to particle physics, physics and astrophysics experiments, and the technology of CERN
- embark on hands-on learning experiences with simple, everyday materials
- embark on model making and game playing
- embark on artistic activities such as drawing, comic making, stand-up comedy, dance and theatrical performances

Learning activities in terms of CREATIONS Approach

SESSION 1

Elementary particles

IBSE Activity	Interaction with CREATIONS Features	Students	Teacher	Potential Arts Activity
Phase 1 **QUESTION:** students investigate a	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured	Students going down at the school garden and engage with teacher's questions and demonstrations, and are	- Going at the school garden: What objects are you seeing around you?	None at this stage.

scientifically oriented question	approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	encouraged to formulate questions relative to the topics of interest .		
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	At the school garden.Students work in groups and explore with the help of the teacher the environment. simple ways in which they can describe or reenact a natural phenomenon	-Students touch, smell, and feel natural objects (leaves,gravel,soil,etc) I call them to pick the littlest grain of soil.	Students engage in creative hands-on experimentation

Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use trial and error .In my question , some of them answered that the little grain who picked up from the soil , was the littliest of all. The best time to speak for molecules-atoms-particles...	-Do you believe that there is littlest grain than this? (activity1)	None at this stage.
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students use their knowledge about molecules, help each other , supported by me ,construct their first molecules.	I made an introduction how little the matter can be. Some students who knew about molecules and atoms helped the others to understand. I gave them notes how to make with plasticine and straws their first molecules (hydrogen, oxygen, ammonia etc.)	Students employ their imagination and creativity in designing and building molecules from plasticine and straws.

Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students in the classroom , watch video about the molecules the atoms , nucleus, neutrons, protons and the electrons's move. In sheets they draw atoms (hydrogen, hellion , etc) according Rutherford's model. Get contact with the periodic table.	I show students a video with the structure of molecules and we speak for the atoms , nucleus, neutrons, protons and the electrons's move. I urge them to make their atoms from plasticine as they see them from the periodic table, according Rutherford's model.	Pupils make their own atoms from plasticine as they see them from the periodic table. 
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process.	Students are invited to present to their classmates their creations, observations and justifications.	I make questions at every working group , about their atoms and the analogy electrons-protons-neutrons, as	.

	Such communication is crucial to an *ethical* approach to working scientifically.		we studied in periodic table.	
Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are enthusiastic for their creations. They want to dramatize their creation and give them life.	I give them an idea. Let's go down and be ourselves the atoms! Making the neutrons, the protons, and the moving electrons.	Every working group dramatized the move of the electrons , the nucleus with the protons and the neutrons at the school yard.

Learning activities in terms of CREATIONS Approach **SESSION 2** **COSMOLOGY**				
IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students got wondered about the big questions: -How did the universe began? -Where did everything start? -Where are we going?	One week ago we had began to read into the class , pieces of the Herbert Reeve's book with the title "The universe explained to my grandchildren". Also we watched videos in our class's projector about the "Big Bang"	

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Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students talk each other expressing their opinions about the creation. Difference between religions and cultures from science. Significance of the science.	What people were thinking many years ago about the genesis of the cosmos and what now, after the science progress through the centuries.	
Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use trial and error . Old opinions for the universe. Is the earth the centre of cosmos?	Questions and answers from the book "The universe explained to my grandchildren". First contact with Edwin Hubble	
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with	Students use their knowledge from videos and books or their pre-Knowledge about genesis. Let's make a model of the	I show to my students a model of the big bang evolution from Tina's Nantsou physic notes.	Students employ their imagination and creativity making in groups cosmic funnels,

	ideas.	big bang's evolution.	I urge them to make their own big bang creations. 	with simple materials. Funnels are made by cardboard, the particles, such electrons, protons, bosons, W and Z etc from rice , lentils, barley, beans, pasta. chickpeas, plasticine. Nebulae from cinnamon and galaxies from salt.
Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students are knowing better Edwin Hubble and his discoveries that the universe expands and the galaxies fend off.	I show students a video indicated to Edwin Hubble and his discoveries to knowing him better. Using Tina's Nantsou cosmology experiments. Cosmos as an expanding balloon.	Students share balloons each other and papers in which they draw galaxies that will glue on the balloons and as they blow them the galaxies will removed from each other.

Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are invited to present to their classmates their creations, observations and justifications. They use dialogue to present and explain everything they made and how it works.	I make questions at every working group , about their creations. I ask how the procedure went, the difficulties and their conclusions.	.
Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are enthusiastic and proud for their creations. They want to decorate the classroom with their creations, explain at their parents what they learn.	I ask them what they want to do with their products. Let's make our classroom prettier. 	Every working group decorate corners of the classroom with their creations. We hang on the cosmos-balloons from a rope through our classroom.

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Learning activities in terms of CREATIONS Approach

SESSION 3

Astronomy and gravity

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of	Students discuss with me and each other about the night stars. Using images and descriptions from the book "The universe explained to my grandchildren" by Herbert Reeves analyze the night sky.	I ask my students if they like watching the sky at day or at night more.	Students make draws of the night sky. They use black font with crayons and bright stars.

	knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	In the computers laboratory Students work in groups and explore with the help of me a virtual journey at the sky . Planets, constellations , galaxies etc are in front of them. We wonder why all these giant cosmic objects have their own position , and orbits in universe. Some students know about gravity.	We go at the computers laboratory and i teach my students the function of the web program solar system (www.solarsystemscope .com) Why stars, planets, galaxies , have specific position and orbits? Do you know the answer? We see in to our classroom video with Einstein and his theories. Contact with space-time curvature.	

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Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use trial and error as they stretch the sheet and observe that the little balls goes straight ahead without making orbits.	How the cosmos would be without gravity? Make an experiment by Tina"s Nantsou training material with a black sheet and a heavy object, simulate the gravity of sun and how it effects earth's orbit.	Students open the black sheet, stretch it and with a big pumpkin in the center forces the little balls to make elliptical orbits.
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students use their knowledge about cosmos objects and discuss for their conclusions after the experiment. Learning for the force-gravity.	I make questions about their observations. How many things can we explain with the gravity force?	
Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Students realize the strength of gravity as she can change the way of light or trap it. Why we see the same light with different colours, during the day?	How strong is this force? Let's talk about light. How the light reach our eyes .How it travels and how fast.	We do a Tina's Nantsou experiment "Astronomy with milk", explain the light and the colours of the sun

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	their evidence and explanations in relation to the original question.		We watch a similar video. The colours of light. The colours of iris.	at sunrise and at noon. Also with a cd the work groups analyze the spectrum of the sunlight.
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are invited to present to their classmates their observations and justifications.	I make questions at every working group , about their observations.	.

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Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are enthusiastic and begin to looking for the solution. They find that transparent plastic pens, plastic rulers, water can give us a little piece of iris's colours .	I give them an idea. Let's find things around us that can analyze the light in his colours , as the cd did.	
Learning activities in terms of CREATIONS Approach **SESSION 4** **Introduction to CERN. Accelerators and Detectors at CERN and their Technological Applications**				
IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured	Pupils have their first meeting with CERN. We watch at classroom's projector a virtual journey at CERN.	Watch video for CERN. Have you heard before about CERN?	None at this stage.

	approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Watching buildings, globe, laboratories , etc. Discuss their pre-knowledge for CERN. Learning about the big CERN's discoveries as the world wide web and Higg's boson.	Learning what acronym means. Through video , we take a lot of informations. What is the big experiment? Remember the particles and talking for the collisions , into the accelerators.	
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students discuss the conditions of the collaboration that must be achieved from all the people at CERN to make successful the biggest experiment in earth. Students discuss about the possibilities to become a scientist , no matter if you are a man or a woman. Speaking for the rights.	Watching a documentary from Hellenic TV station "SKY" which describes many things about CERN , but giving priority to the Greeks scientists who working there. After the viewing , i ask students what they	Pupils draw scientists , men or women, as they imagine them.

			believe for these scientists. . Is it easy working so many people together? What conditions have to be achieved from all these scientists to make this giant undertaking to work right? Do you believe , does it have a meaning if you are a man or a woman to become a scientist?	
Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students use trial and error studying the function of the "magic boxes". Pupils in every work group discuss each other , collaborate , make their conclusions and at the end they make their own sketches . Every work group makes one sketch.	Today we will come in contact with the scientific way of thinking. Watch, study, try, correcting, make it works. In an idea from the education material of the Perimeter Institute	Every work group has his own "magic box", trying to understand how it works. Trying to draw the box's function. At the end every group try to make their own magic

		After making their own models we see if they are functional. All the work teams discuss together for the difficulties, the problems and the solutions that they found.	in Ontario-Canada ia present at the class "The magic boxes". Who do you believe that these boxes work? Study them without opening , discuss your thoughts, use your imagination, talk about your results and at the end draw the inside of the box as you believe that it will work.	box with simple materials (plastic cups or bottles, twine) with the condition to work correct. 
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students remember things that were taught for the atoms and the particles. Use their imagination to dramatize the moment of the collision between protons.	What is going up into the accelerator of LHC? What happens at the colliders and the detectors? Viewing relevant video and pictures from CERN, with particles after protons collision.	Students use their imagination and dramatize the collisions in a detector in our school yard. First a lot of protons collide together and secondly we have a collision into a

			Let's act, making a live simulation. First protons which collide between them and second protons who collide into a detector and how we detect the new particles, as quarks, electrons, bosons etc.	detector, that produce new particles. The detectors detect and record them. All have been with simple materials as coloured sheets and wreaths . 
Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Students in the classroom decided to make their own detectors from plastic bottles .For the simulation of the protons collisions , they will use laser beams. The laser beam will be visual with the help of	How can you simulate with simple materials the CERN's colliders and detectors?	Students connect and paint plastic bottles with colours , make a hole in the middle and put two lasers at the bottles nozzles.

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	their evidence and explanations in relation to the original question.	falling flour over the detectors. Discovering how difficult is to come in the same line the two laser beams.		Then ,they throw over the hole flour and with the lasers on , they can see the beam , simulating the protons collisions.
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are invited to present to their classmates their creations, observations and conclusions from their activities. They have to impress them into their notebooks with photographs, sketches, write up, using every information that can find useful.	I urge my pupils to make an exercise in the physics notebook for CERN.	.

Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Pupils take an image of the the most important technological applications of CERN for society medical, technology etc. Students are enthusiastic for my announcement and begin their group meetings to decide what they will prepare as a crowning for our program.	Learning for the most important technological applications of CERN for society medical, technology etc. Preparing for the next step. I make an announce to my students : "Use your imagination and your creativity to prepare something special that you inspired from all these lessons, activities, videos etc that we have be done . Use simply and easy materials and do your best!".	

Learning activities in terms of CREATIONS Approach **Session 5: Creativity Zone**				
IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through	Work groups decided to cooperate and build a big CERN in to our schoolyard. Studying from the videos and images their project and prepare the materials.	I encourage pupils to construct their handicrafts with simple materials. I show them videos and an aerial view and a close up of the LHC.	

	dialogue with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students discuss the conditions of the collaboration that must be and how this construction will be achieved. Every group takes a part of CERN. 1)accelerators, proton depot 2)Detectors 3)Town and buildings 4)How the construction will be stable in case of wind. 5) Description and analyzing to the other	Encouraging	

		students of our school the construction.		
Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students make sketches on paper the construction and plan the materials. They decide to make the accelerators from toilet cardboards, the town and the buildings from cardboards , plastic basin (globe) and toys, the detectors from painted plastic bottles .	Encouraging	

Phase 4 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students prepared LHC – CERN and set up it in the centre of our school yard. Before this construction my students decided to create their own team –spaceships with the help of our art professor, Efi Tavlariou.	I encourage my students and i feel proud for them!	 

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6. Additional Information

"Playing with physics" was held at the 18th primary school of Keratsini by 26 students of fifth grade. At the end of the year we plan to engage at least 75 students from other classes, in an all day festival who will be dedicated to the science of physics.

Our project inspired by the initiative educational program "Playing with protons" with the encourage , the pedagogical contribution and the science feedback of Ms Tina Nantsou (professor of Physics at Hill school Athens) and Dr Angelos Alexopoulos (Education and Outreach Officer at the CMS experiment at CERN) , whose assistance was crucial to the process of the our project.

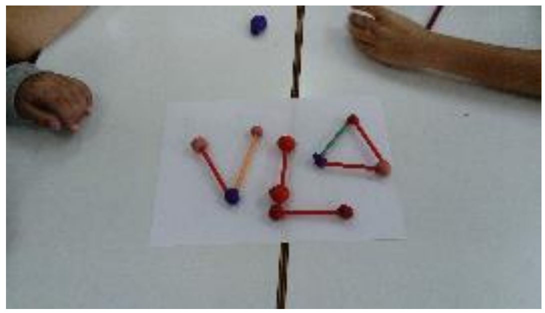
All our project and activities has be presented in our school blog https://paizontasphysics.blogspot.gr/

Photo gallery by session:

SESSION 1 -particles

At school garden

Looking fo the littlest grain of matter…



Making molecules

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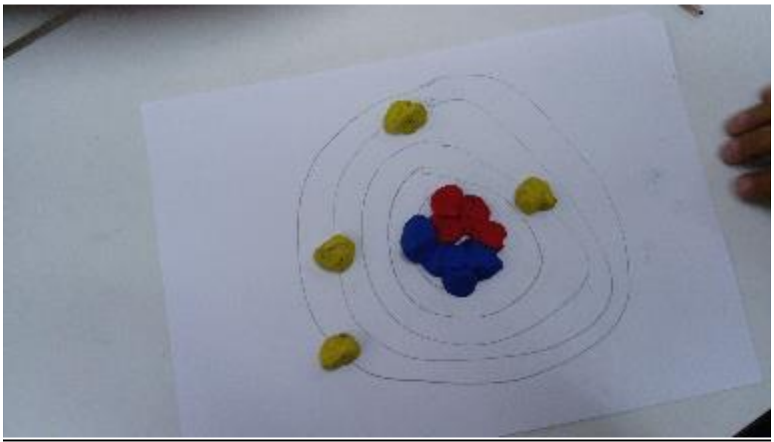


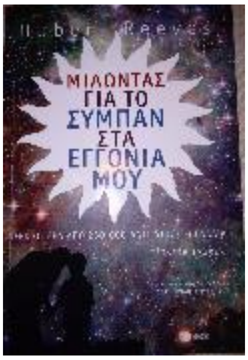
Atoms from plasticine

Also you can watch here our video from our school blog with the parts of an atom and the orbits of electrons

https://paizontasphysics.blogspot.gr/2017/10/blog-post.html

SESSION 2-cosmology

Cosmic Funnels by simple materials



Cosmos expands like a baloon.

SESSION 3 –astronomy and gravity

Representing the colours of the sky at sunrise and at noon.

Curvature of space – time.

More images from this activity at

https://paizontasphysics.blogspot.gr/2018/01/blog-post.html

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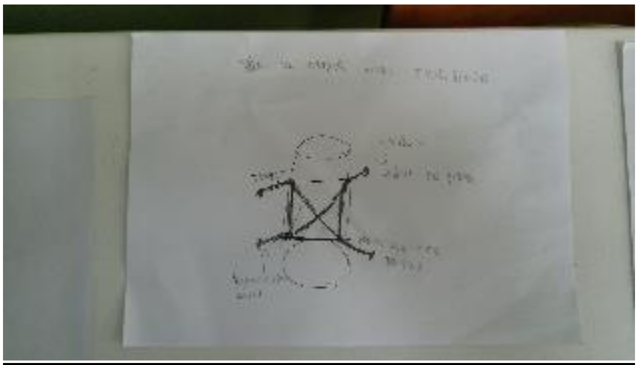
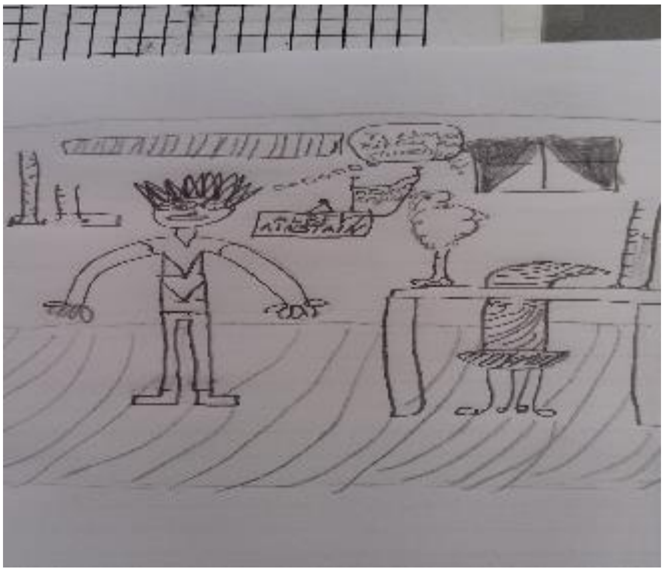
SESSION 4-CERN



Magic boxes and how they work.



Drawning scientists

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In the following ling you can watch our video with the simulation of proton collisions.

https://paizontasphysics.blogspot.gr/2018/02/cern.html

You can watch the video of this activity here
https://www.youtube.com/watch?v=1rb2IeXGLn8&feature=youtu.be

SESSION 5-Creativity

Our spaceships! (many thanks to Mrs Efi Tavlariou , professor of art in our school)

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CERN in our school yard!

More about these activities you can watch here:

https://paizontasphysics.blogspot.gr/2017/11/1054321.html

https://paizontasphysics.blogspot.gr/2018/05/cern.html

7. Assessment

As the project goes to his end (?) the feeling about the educational profit for me and for my students is extremely positive.

25 students of a poor neighbourhood involved in a plan with one and only target.

To get in touch with physics by a different way, using their fantasy, their hands, making experiments and come in contact and understand the big experiment of CERN , in a level of their age.

Because of this project , students loved physics, were anxious for every next activity and came in contact with science with a friendly way as it was the first time in their school life who had this lesson.

Now , students prepare to present this project and some of activities to other students of the school and we believe that a number of 75-80 students will involve in this all day festival of physics at the end of the school year.

8. Possible Extension

This project or some samples of it can be presented at festivals of physics or student festivals with the participation of students and people that interest about science.

Also many activities can be connected with other cognitive objects as history, mathematics , environment lesson etc.

9. References

- **Tina's Nantsou educational material for physics:**

Astronomy,

cosmology

particles

LHC

gravity

- **Herbert Reeves "The universe explained to my grand children"**
- **CERN**
- **Perimeter institute of Ontario Canada**

D3.2.15. A cloud full of knowledge travels to schools and libraries. Cloud Chamber Workshop

Project Reference: H2020-SEAC-2014-1, 665917	**Authors:** **Christos Papandreou & Ioannis Karountzos**
Code: D.3.2.15.	**Contributors:**
Version & Date **April 2018**	**Approved by:** **NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics, STEM, Arts.

1.2 Type of Activity

Educational activities based on Creativity-enriched Inquiry Based Approaches (School based activities and events) and library based activities both of them at local level.

Educational activities that promote school-research center collaboration.

1.3 Duration

2 X 45' (Session 1a & 1b)

3 X 90' [Sessions 2 & 3 & 4 (final check and theatrical rehearsals)]

1.4 Setting (formal / informal learning)

Formal and informal setting could both be combined. So, a preparatory introduction and the consolidation or closing activities could be made at school at Pirgos and Vytina (videos, presentations, quizzes, demos, web conference via Skype) and the main approach (hands-on-experiments, constructions, Puppet Theater) could follow at Vytina's Public Library.

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** Small pupil workgroups communicate and collaborate during the workshop, using the library facilities (books, illustrations, leaflets, wall maps) or the Web (guides and video resources from CERN website: scool.web.cern.ch, Wikipedia: Charles Wilson, Youtube: How to build a cloud chamber and our newly constructed web site). They can also be offered semi-formulated patterns or scaffolds in order to work together and complete their tasks (for example the Standard Model puzzle).

- **Arts-based:** During the assembly of their puppet theatre which includes the cloud chamber or drawing their own cosmic particle figures, they follow a creative form of model making. The preparation of the show and the rehearsals gives them the freedom to express their artistic feelings and thoughts. Especially shy kids through their active participation are encouraged to overcome the communication and socialization hurdles!

- **Dialogic space / argumentation:** Through questioning and dialog students are encouraged to talk about their hypotheses and ideas about this specific experiment and of course propose or explain their choices regarding the method and the way they will complete their activity or the form they will present the results to the public.

- **Visits to research centres (virtual/physical):** As Pirgos and Vytina are far away from research centres or laboratories which are located in big cities, pupils could also contact with specialists via virtual tours or Skype conference in order to learn more about their topic.

- **Communication of scientific ideas to audience:** The artistic performance, whether live or taped, is a very good opportunity for the pupils to share their scientific ideas, especially with the young audiences and their peers. Of course, the announcement in a local TV channel or a modern newspaper or the web (http://users.sch.gr/papandre/, http://dhmotiko-vytinas.blogspot.gr) can rapidly help their ideas to be widespread.

2. Rational of the Activity / Educational Approach

2.1 Challenge

(Description of the problem)

The major event for the initiative to develop this educational action was the absence of space and particle physics teaching at Primary School, since 2006 was the latest year that was taught something similar in the official curriculum, while science is evolving and daily presents new data to society. Especially, CERN, LIGO and VIRGO make up-to-date announcements about the creation of matter as well as the role, the nature and the correlation of forces in our Universe. These are issues that not only excite adults' but also children's imagination. And this is a great chance to become familiar with big ideas and the latest discoveries in particle physics mainly through hands-on experimentation, during school age (Alexopoulos, 2014).

Importance is given to encouraging girls to pursue a scientist's career in the future in order to overcome the established stereotype of male primacy in science. At the same time, a new school culture is sought, in which pupils will strengthen their interest in the scientific way of thinking, and cultivate their physical curiosity about the world of particles in an accessible way, according to their age.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

Our goal is to pass on to the children the message that the occupation of scientists with elementary particles is not something abstract or something that lies only in the sphere of theory. On the contrary, it has applications in practice and especially in the field of medicine for the benefit of people and our society in general. An example is the Positron tomography (P.E.T.).

The idea of a cloud traveling in a cloud chamber, like clouds do in the sky, is symbolic. It symbolizes the journey of knowledge and experience that our students will acquire and spread to their colleagues, from their involvement with an experiment that in 1927 and 1936 gave Nobel Physics and shed more light on the cosmic rays that "showers" our planet. Our experimental layout is already tested and ready to visit our schools, sharing new knowledge and new experience for science.

Our approach is characterized by its humor, imagination, the combination of science and art along with the diversity acceptance. Students will also learn modern concepts of particle physics and how particle physicists work to reveal the hidden structure of nature. This enhances their understanding of how science works, the relative mass of particles and how particle physicists «see» the seemingly invisible. Very important is the fact that allows them to experience science in a fun and less daunting way (Pavlidou, Lazzeroni, 2016).

3. Learning Objectives

3.1 Domain specific objectives

By the end of this workshop, our pupils are expected to have a basic understanding that:

- All matter is made up of the same constituents, that is, elementary particles which compose larger particles, for example protons, neutrons and eventually atoms.
- Elementary particles are too small to be seen by the naked eye or an average microscope, but particle physicists have invented over the last century more and more advanced ways of detecting them.
- One of the first detectors which ware created to study elementary particles was the Wilson Cloud Chamber.
- The aforementioned detector gave new scientific ideas and finally led to the invention of next generation detectors, ending up to ATLAS, CMS, LHCb, ALICE etc.
- To explain in a simple way how Cloud Chamber and of course the modern CERN detectors work.
- The study of particles has and will continue to benefit many aspects of our everyday life mainly through the transfer of technological know-how to medicine, communication, transport and other industries.

3.2 General skills objectives

By the end of this workshop, our pupils are expected:

- To develop collaboration skills by learning to work in small groups around common goals and shared tasks, obtaining group identity.
- To develop problem-solving strategies in order to generate alternative ideas of approaching and completing learning tasks, through hands-on experimentation.
- To unfold their creative power by been encouraged to use their imagination, their language skills and sensory abilities such as storytelling, gaming, model making and theatrical acting.
- To learn by doing and deal with their "mistakes" as a part of the authentic learning process.
- To get accustomed to scientists and science in general.
- To acquire some communication and presentation skills in order to publish and promote the outcome of their collaboration to a greater audience (via press or web or artistically).

4. Demonstrator characteristics and Needs of Students

4.1Aim of the demonstrator

The main aim of the demonstrator is to introduce pupils to particle physics and cosmic radiation by assembling and using the first particle detector, the Wilson Cloud Chamber. This experimental set up is very convenient to be transferred into the classroom or library and used by pupils, of course under the teachers' or specialists' guidance and supervision. The most exciting point of this activity lays to the fact that the pupils will handle almost the same device and apply the same technique as Wilson, who received the Nobel Prize in 1927 for this work!

By doing so, they will apply the scientific method steps in an active manner and then expand their knowledge making links to meta-cognitive procedures, explaining to their peers how did they manage see the cosmic rays, what did they conclude and generally express all of them using multiple techniques (drawings, written text, articles, artifacts or theatrical play).

4.2Student needs addressed

By the end of this workshop, our pupils are expected:

Cognitive

- To acquire knowledge in the field of particle physics and cosmic radiation.
- To learn how to assembly and handle a cloud chamber.
- To learn more about particle detectors and how useful they are.
- To make links between science and society.
- To understand the main goal of CERN.
- To learn about the history behind the first cloud detector.

Affective

- To feel self-esteemed and satisfied after they have met a new learning and scientific experience.
- To satisfy their physical curiosity about the formation of our Universe.

Social

- To participate in work groups, exchanging ideas and options inside and outside the team.
- To support and assist their group members.
- To share and communicate the results of their work.

Psycho-motor

- To conduct an experiment, to play, to construct, to draw, to act as artists.

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5. Learning Activities & Effective Learning Environments

Science topic: Particle physics/Cosmic radiation (Relevance to national curriculum) Not in the curriculum for these ages, as regards cosmic radiation. Class information Year Group: Senior Primary School Age range: 10-12 Sex: both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate) all inclusive	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • Introductory power point presentation on the Big Bang and Super Nova formation • Materials for experimental set up (play dogh, plastic container, flashlight, dry ice, isopropanol, metallic plate etc.) • Materials for artistic experession (colors, color papers, play dogh, cardboards, music cds) • Teacher guidelines from our web site (http://users.sch.gr/papandre/cern) and booklets from Mrs Tina Nantsou • CERN website: scool.web.cern.ch, Wikipedia: Charles Wilson, Youtube: How to build a cloud chamber and document server about particle detectors *Where will the learning take place?* In school and the Vytina Public Library *On site or off site?* On site *In several spaces? (e.g. science laboratory, drama space etc), or one?* In a room that can facilitate lecture and group work *Health and Safety implications?* Pupils need guidance and supervision. Protection measures (special gloves and work glasses) should be taken prior, as dry ice and Isopropanol cause possible burns and irritation. *Technology?*

	PC, tablet or Laptop with Internet access and Projector for power point presentation *Teacher support?* Yes. From our online community (ODS Portal) and personal contact via Skype with our mentors and curators

Prior pupil knowledge Yes. 1 hour introductory session about Big Bang would be preferable. The ultimate aim is to initiate pupils' curiosity by posing a "big question" in Cosmology, taking the challenge not only to acquire new knowledge, but to discover the human and scientific story behind the invention and the 1927 Nobel Prize as well!		
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will: **Session 1a (PowerPoint & Video presentation): To introduce words, names, ideas and terminology around Big Bang, Super Nova and Cosmic Particles and Radiation Physics /// The story of Charles Wilson and his inspiration which arose on the Ben Navis mount (*45'*)** **Session 1b (Hands –on experiment and demonstration): To assembly and handle the Wilson Cloud Chamber and to write down their observations (*45'*)** **Session 2 (Meta cognitive phase and conclusions): To draw an outline with the parts and the phases of the experiment, to talk about the advantages of particle detectors and make links between science and society (*90'*)** **Session 3 & 4 (Presentations & artistic expression): To start preparing the design of the figures and the storyboard of their puppet theater, Complete the preparations of their theatrical approach, present and communicate the outcome to the public and their peers by recording and publishing their performance to their web site or the Youtube (*90' + 90'*)**		
Assessment The quality of their questions, the dialogue and ideas. Mid-term evaluation and support. The quality of their texts, diaries, drawings, constructions and the final artistic performance.	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* The pupils have the opportunity to choice among multiple options, regarding their abilities, maturity,	**Key Concepts and Terminology** **Science terminology:** Particle physics, Cosmic radiation, detectors, LHC, Cern, P.E.T., alpha particles, positrons, muons, cloud chamber. Arts terminology: Painting, puppet theater, digital storytelling, theatrical performance.

	readiness, their age and of course taking advantage the potential of group working and collaborating.	

Objectives:

During this *scenario*, students will:

Session 1a ***(1st day, 45')***

- Be introduced into the new concepts of the evolution of the Universe and the origin of cosmic radiation
- Will become acquainted with the scientists who invented the first particle detectors and their scientific story (*Cognitive*)

Session 1b ***(1st day, 45')***

- Will conduct the basic experiment (Cloud Chamber assembly) under the guidance of their teacher
- Make careful observations, categorize and record them
- To video-record their experiment (*Psycho-motor*)

Session 2 ***(2nd day, 90')***

- Will discuss the results of their observation
- To list their conclusions
- To make links between their conclusions and the science
- To make links between science and everyday life
- To find advantages for the community, deriving from their discussion
- To explain the way they collaborated and describe the steps they followed in order to come to their conclusions
- To suggest alternative ways to search their topic (*Meta-cognitive*)

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Session 3 ***(3rd day, 90΄)***

- To prepare the storyboard and the figures for their puppet theater (*Psycho-motor*)
- Complete the preparations, share roles, assignments and final check (*Social)*
- Perform, record and enjoy their theatrical play (*Social/Affective*)

Session 4 ***(4th day, 90΄)***

- This day may be spent in an out-of-school activity/informal setting (preparation and rehearsals at the Vytina Public Library)

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question *This phase is covered by session 1a*	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by	*Engage with teacher's questions and share their pre-existing experience with each other.* -------- *Watch power point presentation and videos relative to the Big Bang and the origins of cosmic radiation.* *They can also watch a brief video segment about Wilson's life in Scotland and the history of his invention.*	*Teachers will use challenging questions in order to investigate their pupils' first ideas or pre-existing knowledge attracting their interest in the field of particle physics.* --------- *Teachers detect their pupils'*	**None at this stage**

	interdisciplinarity and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.		*expectations. (brainstorming)*	
Phase 2: **EVIDENCE:** students give priority to evidence *This phase is covered by session 1b*	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	*Pupils in work groups follow the instructions and assemble the experimental setup of the cloud chamber. They also take precautions and keep track of the experimental protocol.* *They keep notes of their observations.*	*Teachers guide step by step their pupils and make them feel comfortable to ask assistance or fell free to make any questions helpful for their group effort.* *Teachers check pupils' observations and supply if required.*	**None at this stage**
Phase 3: **ANALYSE:** students analyze evidence *This phase is covered by session 2*	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.	*Pupils further organize, check and compare in groups, through dialogue their evidence* *They "meet" with the terminology for the first time.* *They try to do their first hypotheses and present a first explanation.*	*Teachers carefully monitor their pupils' data and confirm, otherwise they offer more guidance for more careful examination* *Teachers explain the terminology, providing suitable*	**None at this stage**

			sources and presenting examples, according their age and level.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence *This phase is covered by session 2*	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	*Pupils proceed one step beyond trying to draw and reconstruct the cloud chamber model, indicating the steps and phases of the experiment* *They also describe how they reached to the outcome, the difficulties they faced and the solutions to overcome them.* *They can also design their imaginary detector.* *Finally, they give roles to the cosmic particles, for example: alpha particles are a little bit fat, muons are the "bowling balls" and photoelectrons are curly-like!*	*Workshop leaders facilitate and support as required in case the pupils don't remember a step or how to join or handle parts of the experimental setup.* *They also help pupils with their new imaginary "inventions".*	**Students creatively produce something and not only make analogies. They draw a picture with the model of their construction as a meta-cognitive activity (Fig.8, p.20)** **Use of their imagination.**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge *This phase is covered by session 2*	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to	*Pupils discuss with their teachers or specialists about the results and conclusions of their approach and try to connect them with the everyday life, in order to bridge science and society. For example, are there any*	*Workshop leaders facilitate and supports as required.*	**N/A**

	interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	*instruments or machines, constructions or medical device which evolved from the first cloud chamber detector? Are they useful for the people? In what way?*	*They could also schedule a Cern virtual tour for the pupils in order to compare the "ancient" detectors with the modern and sophisticated ones!*	
Phase 6: **COMMUNICATE:** students communicate and justify explanation *This phase is covered by sessions 3 & 4*	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	*Pupils present their work to an audience of classmates and teachers in a school event or to a wider public during a science festival.* *They design the figures of their puppet theater, they draw, they rehearse the storyboard, they share roles, organize the final event.* *They also publish an article with the major evidence for their school newspaper or the school web site.* *They can also share a press release.*	*Workshop leaders and teachers facilitate and support as required.* *They can also help with the correction of the storyboard or the construction of the puppet stage or the arrangements with the public.*	**Artistic expression through puppet theater or digital storytelling.**

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning *This phase can be rejoined with session 2*	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	*Students are questioned about the new acquired knowledge at the end of the workshop as well as to evaluate the process and learning experience.* *They can complete brief questionnaires or make proposals on things that they would like to be changed or to be improved in the next session.*	*Workshop leaders collect and organize this feed-back (pros and cons) in order to improve, change or re-design a future approach.*	**N/A**

6. Additional Information

The scenario for the play can be found on the link here.

Also, resources for the implementation, guides and supportive material can be found on Papandreou blog and on the Cern site.

The online evaluation quiz is available here.

More images from the implementation at the Primary School are shown below:

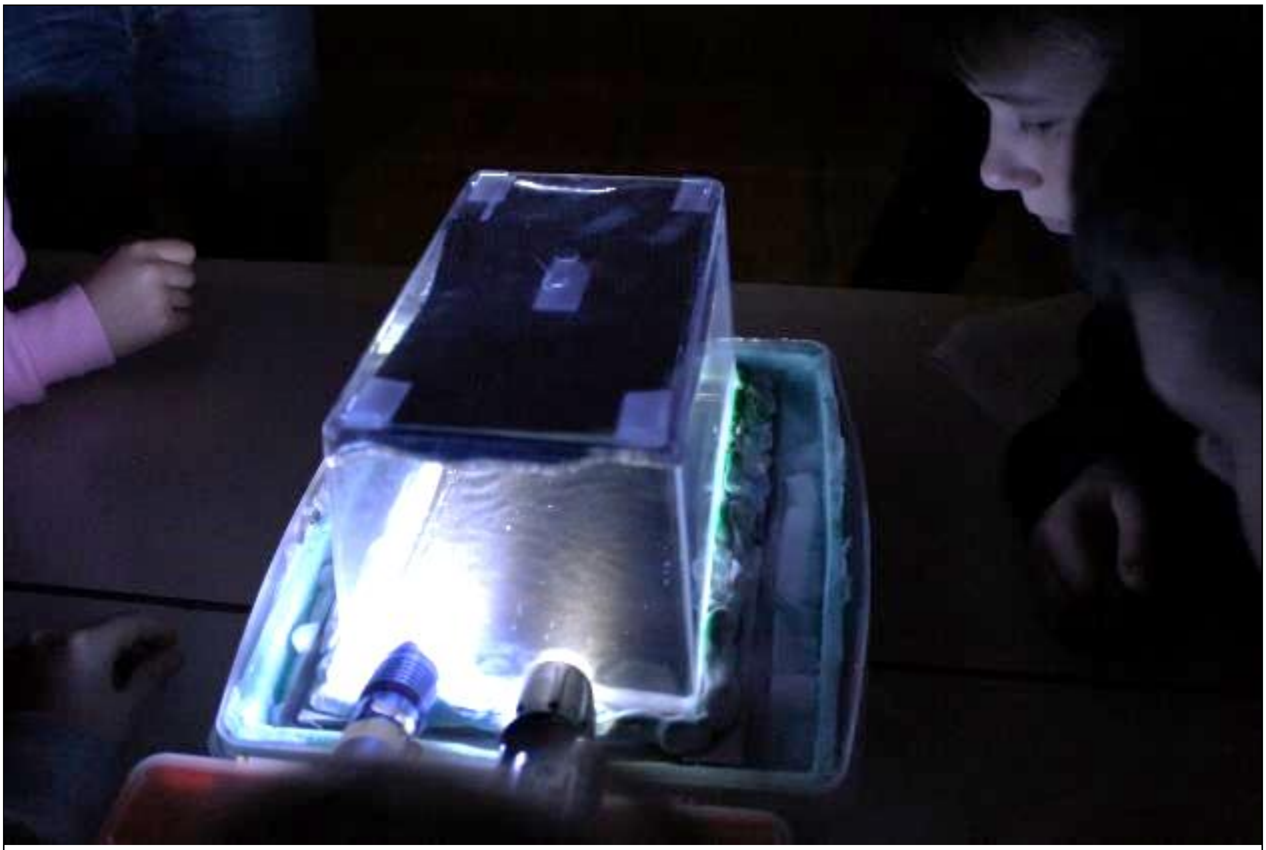

Figure 1. The cloud chamber device

Figure 2. Students gathering the material and getting instructions

Figure 4. Adding isopropanol

Figure 5. Adding dry ice

Figure 6. Observe

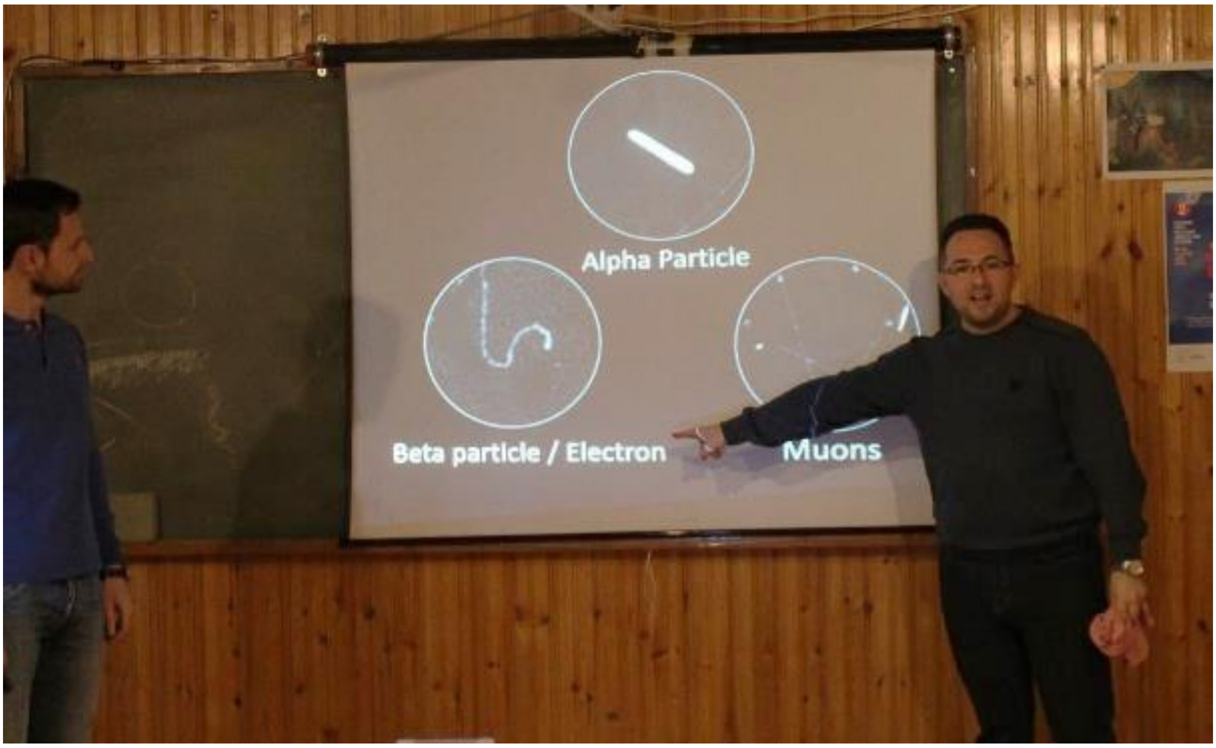

Figure 7. Explanation based on evidence

Figure 8. Drawing a model of their construction

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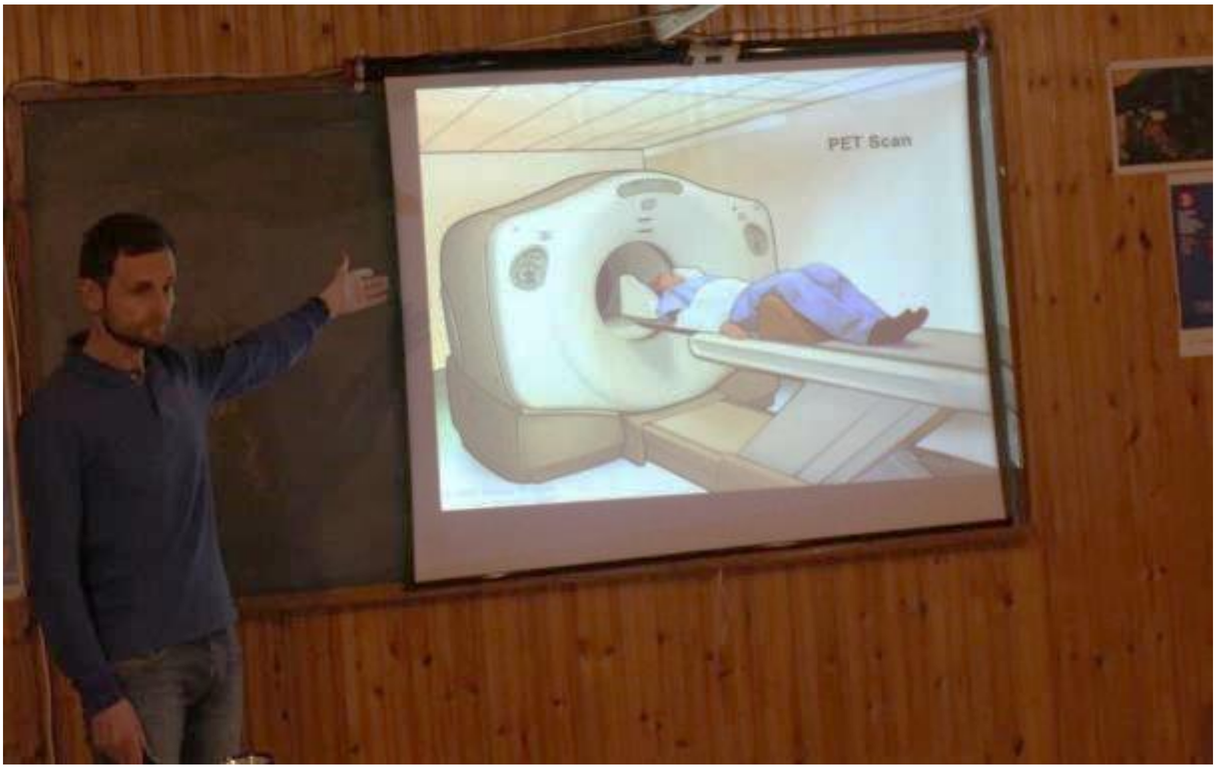


Figure 9. Connecting explanations to scientific knowledge

Figure 10. Students communicate and justify explanation

Figure 11. Science through music

Figure 12. Contributors

7. Assessment

The assessment is carried out through two procedures. The first concerns the qualitative assessment made by the teacher himself during and after the end of the activity. It includes a discussion in which the students articulate their acquired knowledge and opinions, presentation of the projects created during the activity, the operation of the materials and the conclusions that have been drawn. The quality of their questions, the content of their views and the drawings they have created are material to which the teacher relies for the general evaluation.

The second form of assessment is quantitative and includes a series of multiple choice questions that are answered by the students after the completion of the program. It is original material and was created by the teachers of the program. The online quiz can be filled out at http://users.sch.gr/karountzos/Quizes/PwP/Cloud_Chamber/index.html or in the following pages.

Finally, the demonstrator has been evaluated quantitatively by both students and teachers in accordance with CREATIONS assessment protocol that requires the pre- and post-intervention use of the SMQ II questionnaire for students and the VALNET (plus open questions) questionnaire for teachers. More details on the above tools can be found in Deliverable D6.2.

Cloud Chamber

Φύλλο εργασίας μαθητή/-τριας

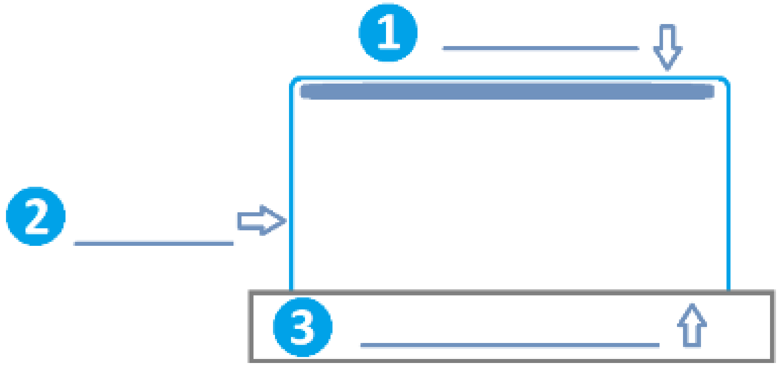
1. Χρησιμοποίησε τον φακό για να φωτίσεις τον θάλαμο νέφους, παρατήρησε καλά τις αλλαγές που εμφανίζονται στην ομίχλη και σχεδίασε στον παρακάτω χώρο τις διαφορετικές τροχιές που βλέπεις να διαγράφονται.

2. Συμπλήρωσε τις λέξεις των υλικών στις κατάλληλες θέσεις του θαλάμου νέφους:

Ξηρός πάγος

Φως

Ισοπροπανόλη



3. Ποια είναι η προέλευση των σωματιδίων που παρατήρησες στον θάλαμο νέφους:
(Κύκλωσε τις σωστές απαντήσεις)

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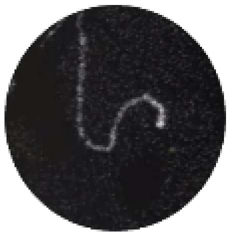
- Ο ήλιος
- Τα σύννεφα
- Το Big Bang
- Η Σελήνη
- Ο ξηρός πάγος
- Οι υπερκαινοφανείς αστέρες (Supernova)

4. Σε ποιο τομέα βρίσκει εφαρμογή η χρήση των ανιχνευτών σωματιδίων; (Κύκλωσε τη σωστή απάντηση)
   - Στην τέχνη
   - Στην υγεία
   - Στη Μετεωρολογία
   - Στην Πληροφορική
5. Έλαβε το Nobel φυσικής το 1927 για την εφεύρεση της συσκευής παρατήρησης της κοσμικής ακτινοβολίας. (Κύκλωσε τη σωστή απάντηση)
   - Isaac Newton
   - Albert Einstein
   - Galileo
   - CTR. Wilson
6. Σύγχρονη μηχανή αντίστοιχη του cloud chamber είναι:
   - Το τηλεσκόπιο Hubble
   - Ο ανιχνευτής CMS
   - Ο Διεθνής Διαστημικός Σταθμός
   - Το Curiosity rover
7. Επίλεξε τα σωματίδια που παρατήρησες στον θάλαμο νέφους.

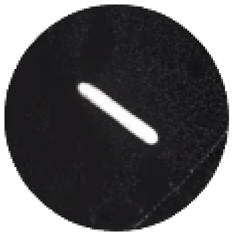
• Σωματίδια alpha	• Πρωτόνια	• Το μποζόνιο του Higgs	• Μυόνια

8. Αντιστοίχισε τα σωματίδια με τις τροχιές που προκαλούν.

Σωματίδια άλφα • •



Μυόνια • •



Σωματίδια βήτα • •

8. Possible Extension

Due to the portability of the appliance and the simplicity of the materials used to assemble it, it can be transported to more school schools in the Vytinas and Pyrgos areas, especially in the collaborating schools of the Play with Protons program, under the guidance of the teachers who implemented it.

The material and guidelines (scenario, powerpoint presentations, videos) that have been published by the teachers who implemented it (Papandreou blog) and on the Cern site, contain useful guides and all the necessary information for the successful implementation of the experiment. The study of the relevant theory is an easy and very interesting task and does not require prior knowledge. For these reasons, it can also be implemented by teachers with little experience in teaching the subject.

Points that need attention is the difficulty to get dry ice supplies in time due to its limited shelf life and the use of isopropanol.

As far as our school is concerned, the activity is going to be presented to the public during the end-of-school events by the students themselves.

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Primary School Of Vytina. (2017). http://dhmotiko-vytinas.blogspot.gr/2018/03/cern-video.html

D3.2.16. Art & Science across Italy

Project Reference:	H2020-SEAC-2014-1 , 665917
Code:	D3.2.16.
Version & Date:	v1.0, 14 May 2018

Author: Angelos Alexopoulos, Pierluigi Paolucci

Contributors:

Approved by:NKUA

1. Introduction / Demonstrator Identity

1.2 Subject Domain

Particle Physics, Physics

1.3 Type of Activity

This activity is a combination of:

- In-school
- Out-of-school including research institute/centre, museum, art space

1.4 Duration

This is a long-term activity that can span across the school year with an average duration of 60 to 70 hours in-school and out-of-school work per school year.

1.5 Setting (formal / informal learning)

The setting is both formal (i.e. school) and informal (e.g. research centre, science museum) and engages multiple actors such as science and art teachers, scientists, artists and even parents.

1.6 Effective Learning Environment

- Communities of practice
- Simulations
- Arts-based
- Dialogic space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Situated with the STEAM movement, *Art & Science across Italy*[6] (Paolucci et al., 2016) aspires to offer Italian (and not only) high-schoolers the opportunity to enter the world of scientific research in particle physics and to express their understanding and interpretation of it through the language of art. The challenge of the project is to break the silos between science and the arts in order to highlight the importance of inter-disciplinary thinking in order for young people to understand and contribute more creatively to the complex process of knowledge creation in a global environment.

2.2 Added Value

Art & Science across Italy seeks to be a model of teaching for transformative experiences in particle physics, physics and more widely in science by following three learning-by-doing strategies (Dewey, 1958; Pugh & Girod, 2007; Garner, Pugh & Kaplan, 2016):

3 *Framing scientific content as ideas*. This involves, first, the identification of "big ideas" in physics and particle physics and, second, the presentation of those "big ideas" as compelling possibilities for young students.

4 *Scaffolding re-seeing.* This involves the provision of guidance and support to students in order to help them relate their everyday world through the lens of particle physics and the interwoven role that engineering and technology play in advancing not only research and discovery in the field but also in promoting knowledge generation and transfer with a positive social impact.

5 *Modelling transformative experiences.* This involves teachers, science educators and even art pedagogists being able to demonstrate to students how cutting-edge science, technology and innovation may change the way they perceive and experience the world.

Art & Science across Italy constitutes an extension of *Science&Art@School* (Hoch & Alexopoulos, 2014) and thus builds on and expands previous educational activities for high-school students, such as 'hands-on' particle physics masterclasses (Long, 2011; Ouid-Saada, 2012; Cecire et al., 2014). Through intensive, collaborative learning episodes that make use of creative and artistic interventions, this activity offers students the opportunity to delve into transformative, aesthetic experiences (Pugh & Girod, 2007) that are considered to increase their deep engagement in science (Biscotte, 2015).

Importantly, during *Art & Science across Italy* students work collaboratively towards the creation of unique artworks inspired by particle physics and related fields such as astroparticle physics and cosmology. These creative objects may be viewed as "artefacts" and, as such, embody motivated use and experiential value (Pugh, 2011). All artworks are then presented by the students themselves in museums, science centres and other public spaces under a common exhibition framework entitled "The Colours of the Higgs Boson"; this is a travelling exhibition curated by the art@CMS programme. All artworks are then evaluated at a local and national level by local and national juries composed of the project's coordination committee with the addition of one or more art experts. The winning artworks will then be incorporated into the art@CMS travelling exhibitions, thereby serving as sources of motivation for and identification with other school communities from around the world (Alexopoulos et al., 2015).

[6] https://web.infn.it/artandscience/index.php/en/

3. Learning Objectives

3.1 Domain specific objectives

Art & Science across Italy rests on the idea that particle physicists and artists share fertile common ground in their parallel efforts to understand '*φύση*' (the Greek word for nature). Creating a bridge between these two worlds is worthwhile since it can help students gain a deeper understanding of each subject area. It can also help them think creatively and responsibly about the collaborative scientific effort being done in CERN, the world's largest particle physics laboratory, but also in other partner laboratories and especially INFN, Italy's National Institute for Nuclear Physics.

Science&Art@School thus takes the art@CMS concept a step further by bringing young students from the science curricula but also from the arts, humanities and social science curricula together with CMS researchers, science educators and art teachers during extended learning periods in order to help students:

- Understand how scientific research in particle physics works
- Explore how researchers and artists work and view each other's world
- Engage in and create artworks inspired by "big ideas" that drive scientific and technological effort at CMS and CERN
- Develop positive and responsible attitudes towards science, technology, collaboration and innovation in large research infrastructures such as the CMS experiment at CERN.

3.2 General skills objectives

Science&Art@School is situated within the movement for approaching science education in schools from a science, technology, engineering, arts and mathematics (STEAM) perspective. The so-called STEAM movement, as reflected in various national and international initiatives on both sides of the Atlantic, calls for arts integration into science teaching and learning as a catalyst for developing 21st century skills that are necessary to thrive in the information age.

In line with the P21® Framework for 21st Century Learning[7], *Science&Art@School* aims to equip students with the following *Learning and Innovation Skills*:

- Critical thinking (e.g. use systems thinking)
- Communication (e.g. utilise multiple media and technologies)
- Collaboration (e.g. demonstrate ability to work respectfully with diverse teams)
- Creativity (e.g. use a wide range of idea creation techniques such as brainstorming)

The above skills are described in more detail in the P21® Framework Definitions document[8].

[7] http://www.p21.org/about-us/p21-framework
[8] http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

As described in Sections 2 and 3, the principal aim of *Art & Science across Italy* is not only to inform, inspire and excite young students about how research in particle physics works but also to engage them effectively through learning-by-doing strategies that employ creative and artistic interventions that take place both in school and out-of-school settings. Ultimately, these interventions focus on providing students with transformative experiences that may also result in the acquisition of 21st century learning skills.

During the 2-year deployment of the project, 3,010 students from 31 high schools in Milan, Venice, Padua, Florence and Naples have participated in the activity. Concretely, the project included: 100 seminars in schools and local INFN institutes, 40 visits to lNFN and other scientific laboratories in Italy, and 28 days of local exhibitions in the aforementioned cities. In addition, 140 were artworks were composed, exhibited and evaluated. Moreover, and as a result of the local and national contests, 150 local and 30 national winners were announced. Finally, 24 winners will visit CERN for one week in September 2018.

The demonstrator requires the active participation of at least four categories of facilitators:

- Science teacher(s)
- Art teacher(s)
- Scientist(s)
- Science centre and/or science museum expert(s) / curator(s)

The involvement of science education specialists, and local educational and cultural authorities or agencies, is also strongly encouraged.

4.2 Student needs addressed

By inviting students to think critically, act creatively and behave responsibly, the *Art & Science across Italy* project speaks directly to the three key aspects of the CREATIONS approach, namely the CREATIONS features, the RRI aspects and the IBSE features. Yet the long-term duration of the activity requires strong coordination among a diverse set of actors and facilitators in order to ensure the successful implementation of all phases of the project. An additional important factor is the extent to which the activity can fit in the school educational system of a country. In the case of Italy that was feasible as the project was implemented in accordance with the "Alternanza scuolo-lavora" framework[9] that allowed an agreement between the participating schools in each city and their corresponding local INFN institutes to devote in-school and out-of-school hours to the project.

[9] http://www.istruzione.it/allegati/2015/Alternanza%20scuola-lavoro.pdf

5. Learning Activities & Effective Learning Environments

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Science topic: Particle Physics, Physics

Relevance to national curriculum:
The activity is in accordance with the "Alternanza Scuola-Lavora" framework that allows schools to build collaborations with research centres (such as INFN) in which students can participate in educational activities that are consistent with the national curriculum.

Class information

Year Group: Senior high school
Age range: 15-17
Sex: Both

Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)

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Materials and Resources
***What do you need? (eg.* printed questionnaires, teleconference, etc.)**
- Computers, Internet (for the particle physics masterclass part)
- Videoconferencing equipment (for the CERN virtual visit part)
- Travel resources for visits to science centres, science museums, art galleries etc.
- Art materials and props (for the production of artworks part)

Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?
- Particle physics masterclass can take place in school or INFN institute
- CERN virtual visit part can take place in school
- Visit to science centre, research insitite is an off site learning activity
- Production of artworks part can take place in school or out of school
- Exhibition can take place museum or science centre

Health and Safety implications? None
Technology? Computers with internet access and videoconferencing equipment for the CMS virtual visit part
Teacher support? Scaffolding

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Prior pupil knowledge
While no prior knowledge of particle physics is required, a preparatory session initiated by teachers is welcomed. In this session, the teacher is advised to ignite students' curiosity by showing relevant audiovisual material or inviting students to do so at home. The ultimate aim is to initiate the inquiry cycle by posing a "big question" in particle physics that will then be followed up by the students. The same process is followed during the 1st formative phase of the project where students get introduced to the project in the form of an open seminar held either in school or in a local INFN institute.

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Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***

During this scenario, students will:

- Be introduced to "big ideas" in particle physics (e.g. The Standard Model, Higgs Boson etc.)
- Explore fundamental concepts and methods of particle physics research (i.e. particle accelerators and particle detectors)
- Analyse real particle physics data with the use of a virtual lab (CMS mini-masterclass)
- Meet and talk to INFN and/or CERN scientists during a seminar or virtual visit
- Be introduced to the interconnections of science and art
- Develop concepts and define design framework for artwork creation
- Create artworks using a variety of media
- Document their creative journey in the form of art statement, visual diary and/or portfolio
- Mount, present and communicate their artworks during the exhibition part of the activity.

Assessment	**Differentiation**	**Key Concepts and Terminology**
- Self-evaluation using the CREATIONS assessment tool - Artwork assessment by local and international jury	*How can the activities be adapted to the needs of individual pupils?* The activity is flexible and interdisciplinary by nature and as such speaks well to a diverse group of students (i.e. science, art and classic lyceums)	**Science terminology:** energy, momentum, charge, Standard Model, Bing Bang, hadrons, Higgs boson, dark matter, antimatter, supersymmetry, Planck scale, string theory **Arts terminology:** abstract, acrylic, harmony, futurism, minimalism, mixed media, montage, mosaic, neutral, perspective, pop art, style, symbolism, triptych, video, animation, sculpture, painting, collage

Session Objectives:

During this scenario, students will:

- engage with big questions about the past, present and future of the Universe (e.g. "where do we come from? What are we made of? Where are we going?")
- attempt to answer and reflect upon these questions, and communicate their interpretation through tools for authentic scientific inquiry but also through creative experimentation and artistic expression

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage in argumentation/dialogue about a scientific topic that may hold social implications but may also influence their personal life choices/decisions Generate with the help of teacher and/or scientist investigable questions through means of authentic scientific inquiry Explore strategies and work structures to answer those questions	Invites students to think of and pose a "big question" in science and particularly in particle physics Ignites students' curiosity by prompting a "big question" in science using audiovisual means (e.g. video) and other scientific information material (e.g. CERN website) Invites students to think of how scientists and artists approach differently a scientific	Brainstorming exercise with science teacher and/or art teacher on how to express a "big question" in particle physics through means of artistic creation. This can take place during the introductory seminar held either in school or local INFN institute. Brainstorming during visit to an art museum, art gallery.

			idea and its social implications.	
Phase 2 **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Take part in a seminar with professional scientist(s) Learn first-hand from scientists the "what", "how" and "why" of scientific work Start to build conceptual bridges between scientific data visualisation and its artistic interpretation	Organizes a visit to research infrastructure (e.g. INFN laboratory) Invites a scientist to give a seminar at school Invites an art educator / artist to help students build interconnections between what they learnt in the seminar or visit to INFN and the world of art	Use of Design Framework for defining core idea, art mediums, materials, process and communication under the guidance of art teacher
Phase 3 **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Work 'hands-on' in groups, analyse and visualise real scientific data from a scientific experiment at CERN or INFN Apply basic principles and laws in physics (e.g.	Science teacher: Facilitates the activity by helping students to connect their analysis techniques with curriculum	Collaborative work in small student teams under the guidance of art and science teacher towards the

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		conservation of energy, conservation of momentum) Embark on artwork production	Art teacher: Invites students to ignite dialogue on the "beauty of science" (e.g. data visualisation) and its potential connection with artistic projects.	selection of scientific topic or phenomenon sought to be represented and/or interpreted in an artistic creation. Development and/ modification of prototypes.
Phase 4 **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Discuss the findings of the masterclass with scientist and teacher. Develop scientific argumentation Explain their own rationale and design framework to art teacher	Science teacher and art teacher act as facilitators	Artworks production phase

Phase 5 **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Make connections between scientific and artistic inquiry Compare different methodologies and skills they used for physics masterclass and artwork production	Science teacher and art teacher act as facilitators	Development of visual diary and/or artwork portfolio, writing up of art statement.
Phase 6 **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	*Scientific investigation part (Masterclass):* Present the results of their analysis to other students, teacher and scientist as part of the CMS masterclass *Artistic creation part*: Present their artworks during the exhibition; they document in a visually appealing manner the development of their artwork from inception to completion. This documentation becomes	Science teacher and art teacher act as facilitators	Art exhibition during which students and teachers communicate their works with the public.

		integral part of the artwork and its communication.		
Phase 7 **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Discuss and reflect upon the evaluation of their work. Explore what worked well and what did not work that well.	Science teacher and art teacher act as facilitators	Art exhibition and associated award ceremony offer opportunities to students for reflection on their creative journey.

6. Additional Information

Detailed information on *Art & Science across Italy* can be found at:

- https://web.infn.it/artandscience/index.php/en/

A selection of moments and artworks from the activity is presented in the photographs below. More photographs can be found on the project's Facebook page.

Students in front of their artwork during the local exhibition in the Science & Technology Museum Leonardo da Vinci, Milan, April 2017.

Students during an award ceremony in the Academy of Drawing Arts, Florence, January 2018.

Awarded animated video by a team of Milanese students. More videos available here.

National winning team during the award ceremony in Naples, March 2018.

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7. Assessment

Art & Science across Italy has followed the evaluation protocol of CREATIONS with respect to both student and teacher assessment. In particular:

- *Student assessment.* Pre- and post-surveys for students aimed at investigating changes in science interest and creativity before and after the intervention were applied. In total, 885 pre- and 345 post-surveys were completed and are ready for analysis by the WP6 team.
- *Teacher assessment.* Following the VALNET framework, 71 teachers in total have responded to a questionnaire aimed at gathering feedback on the feasibility and fruitfulness of the project across various factors including fit with the curriculum, overall satisfaction with the project, etc.

8. Possible Extension

Art & Science across Italy constitutes a large-scale STEAM activity that requires the commitment of multiple actors, from school teachers and students to scientists, artists, art institutes and museums. The initial roll-out of the project from 2016 to 2018 proved to be successful both in terms of student/teacher participation and support of research institutes, including CERN, science museums and art institutes. Based on this, the preparation of the second edition of the project (2018 to 2020) is underway with a possible extension to other fields of science.

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D3.2.17 CERNgineers: Creative engineering in the search of Universe's structure

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Sarantis Chelmis**	
Code:	D3.2.17	**Contributors: Angelos Alexopoulos**	
Version & Date:	**V3, 26 Mar 2017**	**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle physics, physics, engineering, STEM.

1.2 Type of Activity

School – based activities. CERNgineering activities can also be introduced during science fair festivals

1.3 Duration

3 x 90'

1.4 Setting (formal / informal learning)

The setting is mainly formal (i.e. school) but can also be informal (e.g. science cafè, science fair) and engages multiple actors including students, teachers, scientists, parents and general public

1.5 Effective Learning Environment

The learning environment incorporates the following qualities:

- **Communities of practice (web-based/physical):** children work together in an immersive environment of engineering activities. They contact and talk with engineers from various work settings (e.g. tunnel building sector, detector engineering e.g. geospatial enabling technologies, home security systems, road traffic reporting, etc.)

- **Arts-based:** the design and implementation of engineering plans involves children's artistic self-expression as well.

- **Dialogic space / argumentation:** through questioning and dialog children are allowed to express their views regarding scientific research and explain their choices regarding their own engineering artifacts.

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- **Visits to research centres (virtual/physical):** children make use of CERN virtual tours to explore the LHC, the CERN experiment sites and the CERN premises.

- **Communication of scientific ideas to audience:** children present their artifacts to the public and explain the underlying technical details and how their artifacts relate to the particle physics experiments.

5 Rational of the Activity / Educational Approach

2.1 Challenge

(Description of the problem)

The greatest challenge when introducing young pupils in particle physics is the abstract nature of the related phenomena which inhibit conceptual understanding and knowledge development (Wiener, Schmeling & Hopf, 2017). For this reason, we choose to employ a constructivist and multisensory teaching approach (Wiener, Schmeling & Hopf, 2015) and take advantage of multiple intelligences theory. Particularly, thought learning activities we make extensive use of graphical visualisations (i.e the structure of the atom, the Big Bang and the creation of the Universe), of particles anthropomorphism, of physical activities and games representing particle attributes, of artistic expression and problem solving activities and use of ICT learning apps.

At CERN, the European Organization for Nuclear Research, physicists and engineers use the world's largest and most complex scientific instruments to study the basic constituents of matter – the fundamental particles (https://home.cern/about). Education needs to follow up so that pupils get close to the forefront of engineering developments and scientific research.

Even though educating children of younger ages in particle physics is very important for advancement of science, in the long run, and, at the same time, triggers children's interest (Pavlis, 2016), only 3 educational articles have been published over the last 20 years, which focus on particle physics education in primary education context (ERIC database - https://eric.ed.gov/?). This implies a pedagogical knowledge base shortfall in the teaching particle physics at primary school level, which, probably, affects negatively any effort of introducing children in a rather challenging body of knowledge.

At the same time, there is no organized knowledge around key concepts and/or skills concerning particle physics in the form of a comprehensive curriculum. As a result teaching particle physics tends to be rather fragmented, making use of few, quality but isolated learning materials. This makes difficult for children to develop an in-depth and efficient understanding of related scientific concepts and practice skills of organizing, synthesising and evaluating knowledge.

This demonstrator addresses the above need through employing engineering and scientific research activities as a means to simulate and immerse pupils in the culture of the CERN experimental processes. Children develop an understanding of particle physics through facing engineering challenges and visualize, design and construct their own CERN tunnels, accelerators and detectors using simple, everyday objects.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

CERN mission's is to advance scientific research but this is done in an interdisciplinary way with thousand professionals representing multiple disciplines collaborate towards common goals. This means that the process of learning about particle physics has to embrace a corresponding interdisciplinary approach. That is why this demonstrator draws upon the recently popularised STEM education approach (Science, Technology, Engineering and Mathematics), which offers children the opportunity to realize that the advancement of knowledge is depended on tackling challenges, synthesising information and collaborating. This is the interdisciplinary culture we have to educate our children in.

STEM education not only prepares children for the emerging scientific world and the future study and work and choices of career. It helps them shape their intellectual development and their capacity to make informed decisions about political and civic issues and about their own lives (Beatty, 2011). Hands on approach to learning is child-friendly and coincides with the holistic way children perceive the world. Apart from that the problem based learning that is inherent in the STEM education has all the benefits of PBL approaches including high levels of pupil engagement with tasks and creativity.

"During STEM programming, students are creating their own research questions and following a process that helps them learn to investigate multiple perspectives and connect ideas to solve a problem. Whether it's the Engineering Design Process, the Design-Thinking Process, or the Scientific Method, your kids are going to be collaborating with others; asking important questions; taking leadership in their roles; and testing many ideas to reach a solution." (http://www.stemvillage.com/).

3 Learning Objectives

3.1 Domain specific objectives

The main objectives of the teaching intervention are:

- To realize that matter is made up of elementary particles which are structured into larger particles, for example protons, neutrons and eventually atoms
- To explain the methods that physicists at CERN follow to understand the fundamental structure of the universe.
- To explore CERN sites and learn about the role of CERN in advancing research in particle physics
- To explain in a simple way how the Large Hadron Collider (LHC) works.
- To understand that particle physicists collide particles to reveal their inner structure
- To explain in a simple way how particle detectors work and what is their role in the CERN experiments

3.2 General skills objectives

The main objectives are:

- To develop critical thinking and creative thinking skills while facing creative challenges.
- To develop engineering skills while trying out practical solutions to challenges.
- To cooperate effectively with other students
- To develop presentation skills of communicating physics and engineering ideas

- To appreciate the cooperation of different professionals in designing, constructing and operating the world's largest and most complex scientific instruments

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator aims at describing a series of lessons and activities designed to engage students in hands-on engineering experiences, in order to improve their understanding of particle physics. Inspired by CERN facilities and experiments, pupils face engineering challenges and visualize, design, and construct their own CERN tunnels, accelerators and detectors using everyday and simple objects.

4.2 Student needs addressed

Affective

- Experience feelings of joy and satisfaction
- Experience pleasure associated with physical movement and manipulation of materials

Cognitive

- Satisfy curiosity about the structure of the cosmos and the way scientists try to decode universe's secrets
- Gaining basic knowledge and making sense of the way LHC and detectors are functioning
- Game playing and interaction with others (adults, specialists, other students)
- Engaging in fun group activities that has a clear educational purpose
- Freedom of expression to choose their preferred way of designing a particle model
- Develop a sense of self-confidence and pride in mastering particle physics concepts

Social

- Giving to others and obtaining approval, support, assistance, advice or validation from others.
- Experience a sense of freedom to act or make choices.

Task oriented

- Engaging in activities involving creativity
- Meeting high standards of achievement or improvement

5 Learning Activities & Effective Learning Environments

Science topic: Particle physics, physics, engineering, STEM. (Relevance to national curriculum) Grades 5 and 6 _ Science Education Class information Year Group: 5-6 Age range: 9-12 Sex: both Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) all inclusive NOTE: Children of younger ages can be involved in the activities in a playful way and with an emphasis on artistic creations.	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • Power point presentation on (a) the world of particles, (b) the CERN site and facilites and (c) how LCH and a detector works. • Materials for engineering activities • Teacher guidelines *Where will the learning take place?* In school *On site or off site?* On site *In several spaces? (e.g. science laboratory, drama space etc), or one?* In a room that can facilitate lecture and group work *Health and Safety implications?* none *Technology?* Projector for power point presentation *Teacher support?*

	Yes. To encourage and help as necessary

Prior pupil knowledge

The standard model – the world of particles

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Session 1 (power point presentation): Building underground (learn about CERN site and excavations)

Engineer challenge: Build the LHC tunnel!

Session 2 (power point presentation _ videos _interactive games): The LHC (learn the physics and engineering of the LHC)
Engineer challenge: Construct an accelerator! (Use of everyday objects to construct a pipeline for accelerating marbles)

Session3 (power point presentation _ videos _interactive games): The detectors (learn the physics and engineering of the detectors)
Engineer challenge: Construct a detector! (Construct an everyday "particle" detector)

Assessment	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** **Science terminology:**

Accomplishment of engineering challenges - Questioning and dialog through all sessions	Students have the freedom of choice regarding their choices of materials and method of work during engineer challenges.	**Particle physics, particles, particle accelerator, excavations, detectors, CERN** **Arts terminology: video, painting, installation art, literature**

SESSION I

Session Objectives:

Pupils will take an overview of the CERN site and develop an understanding of the human endeavor in constructing those facilities that enable the research on the fundamental structure of the universe.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions. Watch power point presentation and demos. Pupils gain knowledge concerning the main experiments that take place in CERN. They observe that experiment sites are built over the LHC path	Teacher will use challenging questions pictures and demos involving the students to attract the students' interest in the CERN cite and facilities.	**None at this stage**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils engage in engineering activity of tunnel building	Teacher question students to ensure links between observations and conclusions are understood.	**Pupils decorate their models**

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils discuss about the challenge: What proved effective in completing the challenge effectively? What didn't work?	Teacher question students to ensure links between observations and conclusions are understood.	N/A
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils develop a comprehensive idea of the difficulties and challenges of the underground constructions	Teacher facilitates and supports as required.	N/A
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils discuss with professionals about the challenges they face during their work.	Teacher invites professionals of the filed and facilitates and supports as required	**N/A**

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students present their work, after dialog and collaboration within the group, to an audience of students and teachers. They can design and develop a CERN model.	Teacher facilitates and supports as required	**Presentation and explanation of choices in constructions**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the new acquired knowledge at the end of the session as well as to evaluate the process and learning experience.	Teacher initiates the evaluation through dialog and collects and acts on feedback.	**N/A**

SESSION II				
Session Objectives: Pupils will take an overview of the LHC and develop an understanding of it's characteristics and function				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an	Engage with teacher's questions. Watch power point presentation and demos.	Teacher will use challenging questions pictures and demos involving the students to attract the students'	**None at this stage**

	important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Pupils gain knowledge concerning the LHC	interest in the LHC	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils engage in engineering activity of constructing an "LHC pipeline"	Teacher question students to ensure links between observations and conclusions are understood.	**Pupils construct and decorate their LHC models**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils discuss about the challenge: What proved effective in completing the challenge effectively? What didn't work?	Teacher question students to ensure links between observations and conclusions are understood.	N/A
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils develop a comprehensive idea of the difficulties and challenges of the underground	Teacher facilitates and supports as required.	N/A

		constructions		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils discuss with professionals about the challenges they face during their work.	Teacher invites professionals of the field and facilitates and supports as required	**N/A**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students present their work, after dialog and collaboration within the group, to an audience of students and teachers.	Teacher facilitates and supports as required	**Presentation and explanation of choices in constructions**

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the new acquired knowledge at the end of the session as well as to evaluate the process and learning experience.	Teacher initiates the evaluation through dialog and collects and acts on feedback.	**N/A**

SESSION III				
Session Objectives: Pupils will take an overview of the particle detectors and develop an understanding of their characteristics and function				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions. Watch power point presentation and demos. Pupils gain knowledge concerning the particle detectors	Teacher will use challenging questions pictures and demos involving the students to attract the students' interest in the particle detectors	**None at this stage**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils engage in engineering activity of constructing a "particle detector"	Teacher question students to ensure links between observations and conclusions are understood.	**Pupils construct and decorate their "detectors"**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils discuss about the challenge: What proved effective in completing the challenge effectively? What didn't work?	Teacher question students to ensure links between observations and conclusions are understood.	N/A
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils develop a comprehensive idea of the difficulties and challenges of constructing a particle detector	Teacher facilitates and supports as required.	N/A

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils discuss with professionals about the challenges they face during their work.	Teacher invites professionals of the field and facilitates and supports as required	**N/A**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students present their work, after dialog and collaboration within the group, to an audience of students and teachers.	Teacher facilitates and supports as required	**Presentation and explanation of choices in constructions**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the new acquired knowledge at the end of the session as well as to evaluate the process and learning experience.	Teacher initiates the evaluation through dialog and collects and	**N/A**

			acts on feedback.	

Additional Information

The CERNgineers educational initiative was introduced in the 1st Primary School of Rafina during school-year 2016-2017.

Picture 1. First graders working with the "clouds" of the CERN's CLOUD Experiment

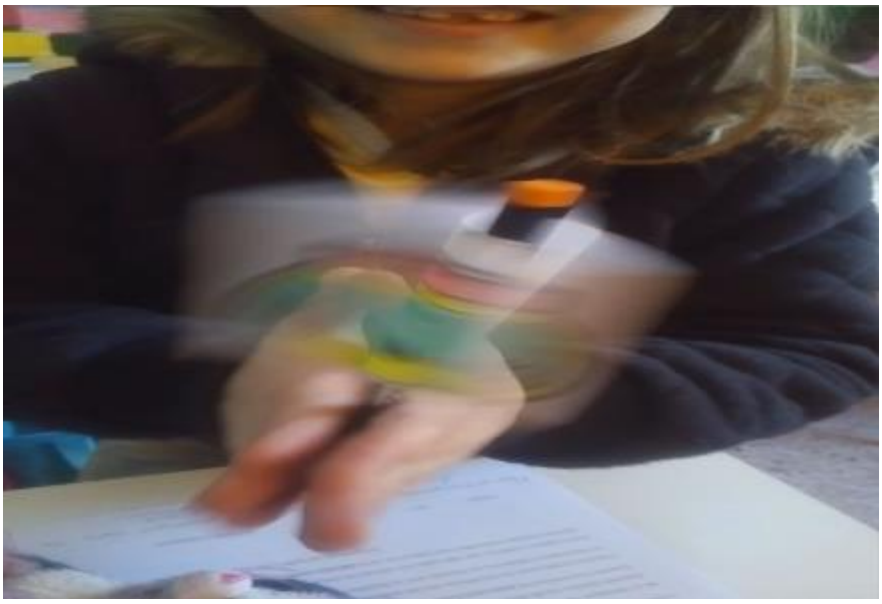
First graders (6 years old children) followed mostly sensory, artful and simple educational activities which, at the same time, reflected main physics concepts and studies conducted at CERN. In this way children developed their own "clouds" (picture 1), made imaginary voyages to the moon, the Mars and the galaxies, and investigated the properties of the magnets through play (picture 2).

Picture 2. Children constructed simple magnet games. An introductory activity to the LHC magnets complex.

At the same time children were introduced in the world of particles following a playful approach: they used magnified glasses to explore the microcosm, created pieces of art (see pictures 3 - 4 and video), learned about light and photons and created little "moving pictures" (picture 5).

Picture 3. Introduction to particle physics through examining sand grains

Picture 4. Sand grains under the magnifying glass



Picture 5. Exploring optics with first graders

The educational intervention at the upper grades followed both a content- and process-driven approach. Initially, children inspired by the Big Bang and the world of particles, created many crafts using the power of their imagination (pictures 6 – 9). Special educational material has been developed in order to support pupils during the process. Samples of the educational material can be found here and here. They also explored aquaponics systems as a means of sustaining life during planet and exoplanet colonization (pictures 10 – 11).

Picture 6. The Big Bang installation created by 6th graders

Picture 7. A Big Bang craft by a 5th grade pupil

Picture 8. The solar system created by 6th graders

Picture 9. 6th graders imagine and reconstruct the world of particles. For more particle "characters" click here.

Picture 10. Aquaponics is a self-contained system that can provide astronauts protein and vegetation (see NASA)

Picture 11. Children learn how to perform water quality tests

Picture 12. 6th graders remove part of the aquaponics system gravel to allow for a leakage repair at grow bed 1. Pupils take intensive care of earthworm population, which move cautiously to a safe place until repair is completed.

CERNgineer educational content and activities were aligned with upper grades National Curriculum. Main curriculum modules like the structure of the atom (picture 13), magnetism (picture 14) and optics (picture 15) were used to support the attainment of the project's objectives.

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Picture 13. The model of the Helium atom created by a 5th grade student

Picture 14. 6th graders explore magnets and their role in the LHC and in particle detectors

Picture 15. 6th graders explore properties of light and get acquainted with photons, crystals and the CMS Crystal Calorimeter

Picture 16. CERNgineer challenges engage pupils in designing their own "particle" detectors

For more information about the CERNgineer project, updates and engineer challenge activities visit project blog archives: http://www.1dimrafin.com/blog/tag/CERN

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6 Assessment

80 pupils of grades 5 and 6 participated to the CERN pre-servey and completed the on-line questionnaire.

Short term gained knowledge is assessed at the end of each session through engineering artifacts, questions and the student presentations.

Evaluation of the activity will also be completed using the evaluation procedures decided by the Creations project team.

7 Possible Extension

8 References

Beatty, A. (2011). *Successful STEM Education: A Workshop Summary.* National Academies Press.

Pending article: Physics Education "Particle Physics for Primary Schools – enthusing future Physicists" by Pavlidou Maria, Lazzeroni Cristina
Article reference: PED-100750

Wiener, J., Schmeling, S., & Hopf, M (2015). Can Grade-6 Students Understand Quarks? Probing Acceptance of the Subatomic Structure of Matter with 12-Year-Olds. *European Journal of Science and Mathematics Education,* v3 n4 p313-322.

Wiener, J., Schmeling, S., & Hopf, M (2017). Introducing 12 year-olds to elementary particles. *Physics Education,* 52 (4).

D.3.2.18.Cultural Collisions at CERN

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Michael Hoch (CERN)
Code:	D 3.2.18.	**Contributors:**	
Version & Date: v1. 30/5/2018		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Art and High Energy Physics at CERN

1.2 Type of Activity

This is a student activity taking place in both formal and informal settings, promoting the connection of school and research center. The activity can take place in local, national and in international level.

Duration

1 school year

1.3 Setting (formal / informal learning)

Formal (classroom) and informal (research center).

1.4 Effective Learning Environment

- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.
- Arts based.

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2. Rational of the Activity / Educational Approach

2.3 Challenge

- Becoming a scientist for a week to participate in modern scientific research
- Employ creativity and teamwork in an artful fashion to achieve ownership on a scientific topic.
- Acquire a critical thinking process regarding advanced scientific topics beyond the reach of school curricula.

In order to understand Nature and the Laws governing our Universe, Modern Science has developed tools and techniques of sophistication far beyond the reach of school curricula. Modern discoveries are able to answer questions such as "What are we made of?", "What is the nature of mass?", "How did the Universe look like during its infancy", which were once in the realm of Philosophy and speculation. Today, these questions can be quantified and answered in cutting edge experiments, thus expanding the boundaries of human comprehension far beyond our everyday practice. In order to organize and conduct the experiments needed to verify such hypotheses, scientists form international collaborations consisting of thousands of scientists and engineers and build gigantic research infrastructures dedicated to the pursuit of fundamental knowledge. Such an international, multicultural research infrastructure is CERN, with experiments ran by thousands of scientists aiming to discover the most fundamental laws of the Universe with unprecedented accuracy.

Students are exposed to these scientific breakthroughs through media such as TV, newspapers, blogs or social media. However, the knowledge and skills needed to be able to comprehend the science behind these discoveries, are far beyond the reach of the school curricula. As a result, dedicated outreach activities have been developed by leading organizations involved in scientific research, science education and outreach, in order to bring students in touch with modern scientific research culture, demonstrate to them cutting edge scientific achievements and cultivate the skills needed in order the students to become 'little researchers' and explore on their own the fascinating world of modern science.

Cultural collisions tackles this challenge using art as a mediator: Students learn about CERN through creative workshops taking place in a week-long exhibition, they produce their own artworks based on science and communicate them in a final student-powered Cultural Collisions exhibition.

2.4 Added Value

- Students learn about cutting edge research at CERN.
- Students get encouraged to create a product as a result of their investigation and research.
- Students learn Physics within and beyond their school curricula and thus get inspired on science in general.
- Students create a dialogue with real scientists working at CERN as well as their home countries.
- Students learn how to communicate their results in an artful fashion by employing their creativity.
- Students develop ownership of complex natural phenomena and scientific methods.

3. Learning Objectives

3.1 Domain specific objectives

The learning objectives of this demonstrator are:

1. The students to Understand how particle detectors work
2. Students learn how data are processed.
3. Students learn about the internal structure of matter and the importance of fundamental particles, which are not part of our everyday world.

3.2 General skills objectives

Students perform scientific inquiries. This way, they develop critical and independent thinking. Students are able to focus on specific details on their chosen topic and follow up their own research, thus obtaining scientific mindsets.

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is a hands-on activity aiming to introduce the scientific culture of large research infrastructures such as CERN to students using art as a vehicle.

4.2 Student needs addressed

In this activity, students develop their knowledge on scientific issues beyond the reach of their school curricula. They develop creative skills, critical thinking and learn how a scientist thinks by doing their own inquiries based on the IBSE model.

The students involved in this activity learn how to: act individually and collaborate, combine the scientific and the artistic mindset using creativity as a bridge, find artful ways to transform specific scientific concepts in abstract artistic expressions, learn how to think as scientists while exploring a cutting edge scientific issue.

5. Learning Activities & Effective Learning Environments

- **Question-eliciting activities**
  - Introductory material addressing the basic needs of the exercise is offered to the participant schools before the inauguration of the Cultural Collisions first exhibition: Powerpoint presentations, possibility for a virtual visit at CERN, videos and interactive simulations are being offered to the schools as resources to prepare students and teachers for the main event.
  - An exhibition is being set up for a week in which scientists and artists will deliver workshops to participant schools regarding science and art at CERN.
- **Active investigation**
  - Students visit the Cultural Collisions exhibition for a day and participate in art and science at CERN workshops (Science Rap, Science Flashmob, Accelerating Colors, Becoming Junior Scientists and filling a junior scientist booklet with information they gather from the exhibition among others).
  - Following the one day workshop, students work with their Art teachers and their Science teachers for the whole school year with the support of the Cultural Collisions artists and scientists, in order to produce their own artworks inspired by a CERN related theme.
  - By the end of the school year, students will present their artworks in the final, student-powered Cultural Collisions exhibition.

Science topic: High Energy Physics/Nuclear Physics. Class information Year Group: 1st to 3rd class of senior high school Age range: 14-18 Sex: both Pupil Ability: Basic computer usage required	Materials and Resources: For the exhibition: Exhibition material (posters, laptops, printed material and virtual resources, internet access). For the in-school activities: PC, internet, video-processing software, paint, paper, other exhibition material. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In a computer laboratory, exhibition centre, arts room and a classroom. *Health and Safety implications?* None *Technology?* *Teacher support?* The teacher will provide the students with preliminary material and is advised to discuss with them before the beginning of the activity. The relevant material can be found in this online virtual community: http://portal.opendiscoveryspace.eu/community/cultural-collisions-848012
Prior pupil knowledge: The students involved in this activity need to have basic knowledge of particle physics and detectors, provided to them before the first exhibition.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* By the end of the final exhibition, students should be able to understand fundamental aspects of particle physics (basic ideas about fundamental particles and interactions), particle detection techniques, to have an overview of the functionality of big particle detectors such as CMS at CERN, to understand how we accelerate and collide particles and to have an idea about the history and purposes of large research infrastructures such as CERN.		
Assessment Content knowledge is assessed through specific questions and exercises throughout the in-class activity and creativity as well as science motivation are assessed through pre-post questionnaires.	**Differentiation** The activities described in this demonstrator refer to very advanced scientific concepts and the attempt to bring them in the classroom. As a result they have specific content knowledge requirements. Variants of these activities including a presentation and creative expression of students combined with a virtual visit can be performed by more students without tight content knowledge restrictions.	**Key Concepts and Terminology** Particle collision, Data Analysis, Particle Acceleration, Particle Detection, Arts and Science, Science flashmob, masterclass. **Science terminology:** Particle collision, Data Analysis, Particle Acceleration, Particle Detection **Arts terminology:** Rap, drawing, poetry, dance, music, visualization, video design, sonification
Session Objectives: Students will learn how to present advanced scientific topics in an artful fashion.		
Learning activities in terms of CREATIONS Approach		

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	Students do a full day visit at the cultural collisions initial exhibition (http://portal.opendiscoveryspace.eu/en/edu-object/cultural-collisons-canada-exhibition-osc-science-centre-april-2018-850558, https://www.youtube.com/watch?v=ikNhOlXtdgQ), taking place for a week in their area. During the visit, students participate in various workshops, such as SciArt workshops and others (http://portal.opendiscoveryspace.eu/en/edu-object/cultural-collisions-introductory-workshops-850946	The students are accompanied by their arts and science teachers in the cultural collisions exhibition. The teachers also participate in the workshops as spectators and collaborate with the experts of the exhibition in order to get further insight on the topics and methodologies presented.	

		http://portal.opendiscoveryspace.eu/sites/default/files/culturalcollisionscanadaorigin_cmsweekapril2018_final_1.pdf, https://www.youtube.com/watch?v=ixlWlq3_paw) connecting science at CERN with art and investigate the question of: What are the constituents of our world? How do we accelerate and detect elementary particles? What is CERN? What is CERN's mission?		
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Drawing ideas from the Cultural collisions exhibition, students initiate a school-year-long project based on one or more scientific investigations (e.g particle detection, Higgs particle and others) they can work on and perform further studies on	Students will work closely with their science teacher in order to choose the topic of their investigation . To assure a solid content knowledge of the students, the teacher can use the support of the collaborating scientists of the Cultural	

		the topic to assure sufficient content knowledge.	Collisions Exhibition, which can be assured through virtual or live meetings, through the development of dedicated educational resources for students and others.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	After having decided the science topic they will pursue, students collaborate among themselves and with their arts teacher and determine the artistic methodologies (science rap, dance, flashmob, creating sculptures, drawings etc) they will implement.	The majority of the creative work is done with the arts teacher within their teaching hours (or beyond), with the support of the science teacher, due to the advantages that the arts curriculum flexibility presents.	All this activity is based on art.
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students generate their scientifically inspired artistic intervention. The intervention might vary from a theatrical play, to an exhibit, a dance show, an artful video or something	The arts and science teacher acts as a coach and consultant, while students take the responsibility of generating and finalizing the artistic intervention.	All this activity is based on art.

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		else. https://www.youtube.com/watch?v=sdB2PydXUW8		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students finalize their artworks and review them with their classmates and teachers making sure that they manage to convey the scientific topic in question in a coherent fashion. Students incorporate the feedback from their teachers and classmates and produce the final version of their artistic intervention.	Teachers provide feedback to the students regarding the connection of their artistic interventions with the scientific topic they have chosen.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students participate in the final Cultural Collisions event taking place in their city in which they present their work and share their results with other participant schools, experts and public.	The teachers support their students with the preparation and	Students communicate their work through an artistic

		https://www.youtube.com/watch?v=BIy_iERk5Ps&index=8&list=UUCfnA94VmJ4YprdwOyu_dtw	implementation of their artistic intervention.	intervention.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students of different schools connect among themselves and discuss their experiences. They discuss their artistic interventions with teachers and Cultural Collisions experts and obtain feedback which will help them reflect on the topics they pursued and methodologies they followed.	Teachers mediate a productive dialogue between students and between students and experts to help them obtain high quality feedback on their work.	

6. Additional Information

All relevant companion resources and activities can be found in the dedicated online community of the CREATIONS portal http://portal.opendiscoveryspace.eu/en/search-resources-in-community/848012

7. Assessment

The student motivation and creativity is monitored using dedicated evaluation questionnaires developed by the CREATIONS consortium before and after the completion of the activity. The content knowledge is monitored throughout the lesson through dedicated questions and exercises which are done in a hands-on fashion.

8. Possible Extension

After the end of the Cultural Collisions activities, students might work further in order to create a smaller permanent Cultural Collisions exhibition in their schools which will be open to the public with students as guides.

9. References

- https://rachaelnee.art/artcms-sciart-booklet/
- http://lifelab.org.in/images/resources/sciart/SciArt_Feynman_Inspired_Art.pdf
  - http://mhoch.web.cern.ch/mhoch/Art@CMS/Art@CMSprojects.pdf

D3.2.19. Artful Physics

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Chappell, K. & Hetherington, L.
Code:	D 3.2.19.	**Contributors:**	UoE, EoB, STFC
Version & Date:	**16. 5. 16 final**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics (particle and nuclear)

1.2 Type of Activity

School-based large scale national activities

1.3 Duration

9 months

1.4 Setting (formal / informal learning)

Informal as not within curriculum time, but connected to appropriate English Science curriculum

1.5 Effective Learning Environment

- Communities of Practice
- Arts-based
- Dialogic space/argumentation
- Visit to research centre
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Often in science education there has been an emphasis on teaching approaches that are rooted in scientific method (e.g. argumentation, practical work and investigation). These often lead to communication of scientific ideas using genre-based reporting that pupils can find disengaging. Increasingly science teaching practice has begun to engage with more creative and arts-based methods of teaching and learning. The CREATIONs UK Artful Physics science competition aims to contribute to this growing community of practice to bring the arts into science education in order to develop students' understanding and to communicate this understanding to their peers and the wider science community. The competition is purposefully open to representation via any artform in order to create possibities for musical, aesthetic, virtual, embodied etc manifestations of scientific ideas. It is the aim that these will better engage students in the process of understanding and representing the ideas and in turn will better engage other young people in science via the arts.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The competition aims to build on understanding of creative practice developed in the last 15 years across Europe. In particular, via its community of practice it is hoped that the competition website with its sharing space, forum and mentoring activity from arts and science experts, will create a virtual Living Dialogic Space. Drawing on Chappell and Craft (2011) this means being able to create a working space in which hierarchies are flattened, co-participation is encouraged, young people are empowered and multiple perspectives are honoured (in this case via the multiplicity of arts practices that will be used). Crucially it also means allowing young people to raise questions which generate new ideas but also maintain an open space of possibility for new questions (drawing on Bakhtin, ? articulation of dialogue). Again using arts, aesthetic, embodied and multi-modal representational formats allows for this to happen, whilst being integrated with inquiry-based science (IBSE) where appropriate.

Through the arts-science interdisciplinarity, it is also an aim of the competition to encourage an ethically-driven form of creativity (perhaps humanising, Chappell, 2011), that uses the potential of the arts to move away from marketised, 'work-force of the future' understandings of creativity (Seltzer and Bentley, 1999). And to forefront individual, collaborative and communal creative approaches, whilst acknowledging that while young people make they are also being made (Chappell et al, 2011).

Finally the competition has the capacity to encourage possibility thinking (E.g. Craft, McConnon, & Matthews, 2012). This means being able to ask 'what if' and 'as if' questions. For example:

- What if I/we choose to explore this scientific question rather than that one…?;
- What if I/we use this arts approach to help me explore my question...?
- How can I/we imagine this as if I were…?;

3. Learning Objectives

3.1 Domain specific objectives

A key objective of this demonstrator is to engage pupils with important concepts in physics and develop their understanding of these ideas through exploration and communication. The overarching objectives of the demonstrator are to engage and enthuse young people with physics through interdisciplinary activity and competition.

Through engaging in the competition, pupils will be able to:

- Explain the key concepts in physics with which they are working, appropriate for their age (e.g. particle physics, space physics, waves, light, forces)
- Communicate scientific concepts using multiple modes
- Use the internet to liaise with scientists and artists to develop their ideas
- Collaborate with peers to develop their piece of work
- Develop their skills and understanding within a particular artistic discipline (e.g. dance, visual arts, music)
- Ask questions relevant to the science and arts content/contexts they are using
- Scientific interconnection of science with aspects of arts (students will create a multi-disciplinary piece of art work which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).

3.2 General skills objectives

In the context of the Artful Physics competition, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Develop spirit of cooperation and teamwork
- Develop communication skills
- Students will gain knowledge and experience with group-work

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give pupils across a wide age range the opportunity to create a piece of art work that explains a key concept in physics. By doing so, they will both enhance their understanding of physics and develop their interest in an element of physics beyond the possibilities available within class time, whilst developing their artistic understanding and skill. The final stage of the competition involves prize winner events hosted by RALL/STFC with a 'money-can't-buy' prize (e.g. firing the RALL laser).

This demonstrator aims to encourage pupils to develop their understanding of, and engagement with a particular topic in physics by harnessing the creations 'features' of creativity. The image below shows how these features are present within this demonstrator.

4.2 Student needs addressed

This demonstrator addresses students needs beyond the possibilities inherent in the national curriculum, giving them opportunities to be playful in investigating and communicating a concept in physics in creative and engaging ways. Pupils have a range of topics they can select from, all relevant to the English National Curriculum but addressing aspects that are often areas where teachers may lack specialist subject expertise (e.g. Primary science and a lack of specialist Physics teachers at Secondary level). By working with professional scientists and artists through the online competition mentoring forum, students will have enhanced opportunities to focus on the questioning and communication aspects of scientific inquiry whilst engaging in dialogue and collaborative work, and their chosen artform.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

Science topic: Working scientifically (KS2-4); using secondary sources as evidence, spotting patterns through physics topics (KS2) Space physics (KS3) Atomic structure, nuclear fission, fusion and Sun's energy, space physics (KS4), quantum physics, astronomy (KS5) **Class information NA** **Year Group:** **Age range:** **Sex: both** **Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need?*** **Competition url, judging criteria, access to Professional scientists and artists via website, access to arts/science materials through school or home, passion for science idea** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **Anywhere** ***Health and Safety implications?*** **NA** ***Technology?*** **Access to competition website and ability to upload artwork or filmed version of art work. Technology as appropriate to idea.** ***Teacher support?*** **Not necessary but both science and arts teachers may facilitate if available**
Prior pupil knowledge **Dependent on age range/topic**	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **During this scenario, students will** **The competition does not function within a classroom lesson, see objectives above for wider learning possibilities**	

Assessment **Competition will be judged by an expert panel of partical physicists, dance/drama/visual arts/creative writing/music and film specialists.** **Criteria are: Evidence of creative thinking, e.g. a way new to you of exploring, explaining or showing your question** • **Correct science when exploring and explaining your question** • **A high-quality final product (in whatever format has been chosen), in both art and science, which crosses the boundaries of individual subjects and themes.** • **Enthusiasm and passion for tackling the project**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Competition has age specific categories, and mentoring is available to all entrants to ask questions specific to their needs (differentiation by support)	**Key Concepts and Terminology** Varied – see possible curriculum connections above **Science terminology:** Physics, Light, waves, astronomy, quantum physics, Higgs-boson, particle, scale, atom, atomic structure, nucleus, proton, neutron, electron, quark. **Arts terminology:** Dance, visual arts, music, film, poetry, animation, fiction, narrative, theatre, drama, rap, choreography, composition

Session Objectives: NA
During this scenario, students will

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student (Teacher)	Potential arts activity
Phase 1:	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through	Children and young people will choose an art form to best represent their science topic, perhaps using IBSE. This is however unlikely to	

QUESTION: students investigate a scientifically oriented question	*dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	map directly onto the IBSE stages to the left, but to encompass science knowledge/processes in a more holistic way e.g. through a film with narrative; through a dance performance embodying a science concept, through a poem engaging with key physics principles. They may ask teachers for assistance if they are available but are also likely to draw on artist/scientist expert mentoring via the competition website.
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	
Phase 5: **CONNECT: students connect explanations**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary*	

to scientific knowledge	knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	

6. Additional Information

This demonstrator is a collaboration between University of Exeter, University of Birmingham and STFC.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

Demonstrator activity will be assessed by using the CREATIONs features as part of the judging criteria for the competition. Those students who attend the competition events will be asked to fill in the CREATIONs assessment questionnaire. It may be possible to make the CREATIONs questionnaire available online for all entrants to fill in, but this depends on the technical capacities of the CREATIONs web teams.

8. Possible Extension

It is possible that this demonstrator will be extended to form part of a larger international arts/science competition. This will involve collaboration with CERN who are also running Austrian and Swiss arts/science education national competitions.

9. References

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D3.2.20.WILD, Science Art Ocean

Project Reference:	/H2020-SEAC-2014-1 , 665917	**Author: Suzie West, Nikita Hall, Kerry Chappell**	
Code:	D 3.2.20	**Contributors:**	
Version & Date:		**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science / Arts

1.2 Type of Activity

Educational Activities based on Creativity-enriched Inquiry-Based Approaches (school based)

Local

1.3 Duration

5 sessions of 4hrs in length across a 3 month period per cycle.

This cycle was completed twice.

1.4 Setting (formal / informal learning)

Formal learning within curriculum time and informal learning where students continue with their project into their own personal time out of school during evenings and weekends.

1.5 Effective Learning Environment

Communities of practice

Arts-based

Dialogic space/argumentation

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Students' approach to science can be to see it as transmission-led learning focused on learning scientific facts, when in fact school science has the capacity to be about the dialogic relationship between important questions and how we use knowledge to answer these creatively. There can also be a tendency to approach science in a risk-averse way which is detached from students' real-life experiences because of the pressures of attainment targets. This Demonstrator is therefore designed to work between the arts and sciences to put curious questioning at the heart of learning. It is also designed to strongly relate to students' identity development as investigator and its relationship to their local geographical environment. Science and creative arts subjects are interwoven through investigation and not overly articulated or polarised in the process. The outcome of the project is open ended and bespoke to each student, giving them freedom and also an opportunity to develop individuality in their response.

2.2 Added Value

The added value of the demonstrator is that it motivates students to engage with developing their understanding of the sciences and the arts by putting their interests, questions and identity at the heart of the learning process. The Demonstrator offers an unusually open learning format within which students can explore questions that relate to their interests and lives in their home geographical environments – via this they are motivated to explore relevant areas of the science and arts curriculum at their own pace and through their own lens. In order to achieve this, the Demonstrator is directly designed around the CREATIONS features of Risk Immersion and Play, and Interdisciplinarity.

3. Learning Objectives

3.1 Domain specific objectives

Wild Project

- Encourage students' interest in science and research through investigation
- Guide students on how to independently work through a process of enquiry, exploration and communication of ideas
- Initiate contact between students and other professionals such as story tellers, dancers, physicists and film makers
- Bring schools and participating students closer to local community and their outdoor landscapes
- Engage parents, primary schools and the general public into schools' happenings and events
- Encourage each student to 'showcase' themselves and their new identity as an investigator and disseminate research through an exhibition, presentation, performance or workshop.
- Showcase the potential for creative arts and science to be regularly interwoven in engagement with feeder primary schools, affiliated schools and organisations.

3.2 General skills objectives

In the context of WILD, students' general skills objectives are to:

- Actively participate in the negotiation of scientific and artistic concepts
- Develop enquiry, imagination and communication skills
- Scientifically interconnect science with aspects of art (students will create a multi-disciplinary artistic outcome which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- Develop a spirit of risk, play and curiosity.
- Connect the science classroom with their local landscapes

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the Demonstrator is to give secondary science students the opportunity to understand that school science can be about the dialogic relationship between important questions and how we use knowledge to answer these creatively. The Demonstrator allows students to learn arts and science skills and knowledge of their choosing driven by their own questions related to real life. The project is addressed at students aged 12 - 15years old, and also includes a science teacher and arts teacher collaborating together and providing subject specific knowledge as appropriate to students' investigations, as well as generic support centred around the notion of being an 'investigator'. The Demonstrator also aims to engage students in risky learning whether that be physical, emotional or cognitive risk by encouraging them to learn playfully and in an immersed way through leading their own individualised project with an open-ended outcome.

The activities are designed to put students' own questions, identities and connections to local community and environment at the heart of their investigations. The students are introduced to place through a particular lens, each place and each lens being different. This may include a story teller bringing to life an historical figure and his engineering of a local theatre, a physicist taking them on an interactive tour of the local museum, or a dance practitioner and gallery tour guide facilitating a movement exploration of horizons, shapes and abstraction of coastal landscapes. The plurality of the outcomes, questions, practitioners and places is a useful tool for encouraging open-endedness and a community of practice.

4.2 Student needs addressed

The risk, immersion and play experiences of this project require the teacher and practitioners to provide a safe and supportive environment where the students feel they can make mistakes, try new things and challenge themselves physically, socially, cognitively and emotionally. The physical risk involved in the project is low, but the independence of the students when on site means that risk assessments and teacher observation is completed before each trip. Over protection, too many rules or constant negative language to manage behaviour can be detrimental to the project and the individuals' ability to take risks and develop independence.

5. Learning Activities & Effective Learning Environments

Each cycle included a trip to a minimum of two geographical locations, often landmarks or local beauty spots. The introductory workshops at each site took one or two hours of the 4 hour trip interweaving the creative arts and science through performance, workshops and interactive exploration. Derives were used in every site so the students could observe, hear, taste, and touch the landscape they were in. This was also combined with a photographic quadrant during their Derive, interweaving the science and arts together through observation.

The students also spent at least one workshop day in the Creative Arts and Science departments investigating and designing their final outcomes. These were shared as an exhibition at school, a local gallery, a performance in a local museum and films along the coastline.

Science topic: Bespoke to student Quadrat sampling and scales Biological study of coastline Tides and horizons Geological study of cliffs Physics of telegraphs, sound under water, Kinetic energy (Relevance to national curriculum) Class information Year Group: 8, 9 & 10 Age range: 13- 15 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *Printed questionnaires and booklets for Wild Investigators* *I-Pads or cameras* *Art Materials* *Quadrats* *Space: Science laboratory, drama or dance space, art room or messy play* *Health and Safety implications:* *Teacher ratio for trips* *Technology: Internet, IPads, Film making equipment* *Teacher: Creative arts teachers, science teachers and guest practitioners.*
Prior pupil knowledge Basic art science and drama skills from Ks3. They will select their own subject and develop their knowledge to support the path of enquiry.	

Individual session project objectives During this scenario, students will Investigate their local environment Develop a presentation, performance, exhibition piece or film that communicates the result of their personal enquiry.		
Assessment No assessment for this project. Some students have used it as evidence for Arts Award.	**Differentiation** The open-ended format of this project means that the students differentiate through outcome. Support is offered to students on a 1:1 basis by the teachers supporting the project	
Session Objectives: During this scenario, students will		
Learning activities in terms of CREATIONS Approach		

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Explore one or two sites and make initial observations They are encouraged to go where their interests and curiosities take them and are asked to consider both scientific and artist lenses- wearing bi focal glasses! At the end of the day each student develops some curiosities/ questions about their explorations	Plans the routes and some workshopping activities Observe and support the students Expand and encourage their questioning	**Derives, sketches, guided walks, blind folded partner navigation, photographic quadrats, free-writing, improvisation games exploring the architecture of the shapes in the space.**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students return to the sites or close by sites to observe, explore and record more observations and interpretations of the places that interest them most Devise and develop deeper ideas about their chosen area, interweaving scion and arts lenses	Teacher supports the students explorations and runs or organises two workshops which offer plural perspectives on the sites e.g. story teller and physicist exploring the telegraph museum. artist and georgrapher interpreting town scapes	**Phase 2: Watching performances or attending workshops, independent research as sketching, filming and devising, group discussions**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Research, sample and analyse their data Pooling words, images, thoughts, feelings and listing elements	Lead an open discussion about perspectives, questions, analysis Run 1:1 tutorials with each investigator	**Phase 3: Group discussion, research and word collages, mind maps, physical demonstrations**

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	. Reflective diary entry or blog on their thoughts Selecting key words, data and images to create a mood board. Annotate the mood board with their answers and ideas about HOW WHY WHEN WHAT	Guide reflections with challenges and questions Set deadline for mood board and presentation of their mood board by the end of the session	**Phase 4: Mood boards, presentations, film diaries**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Plan, create, design rehearse, an outcome that connects their experience to a key message	. Offer space, rehearsal guidance and materials for the students to begin their process from enquiry to explanation.	Phase 5: Devise, create and rehearse the dance, art,

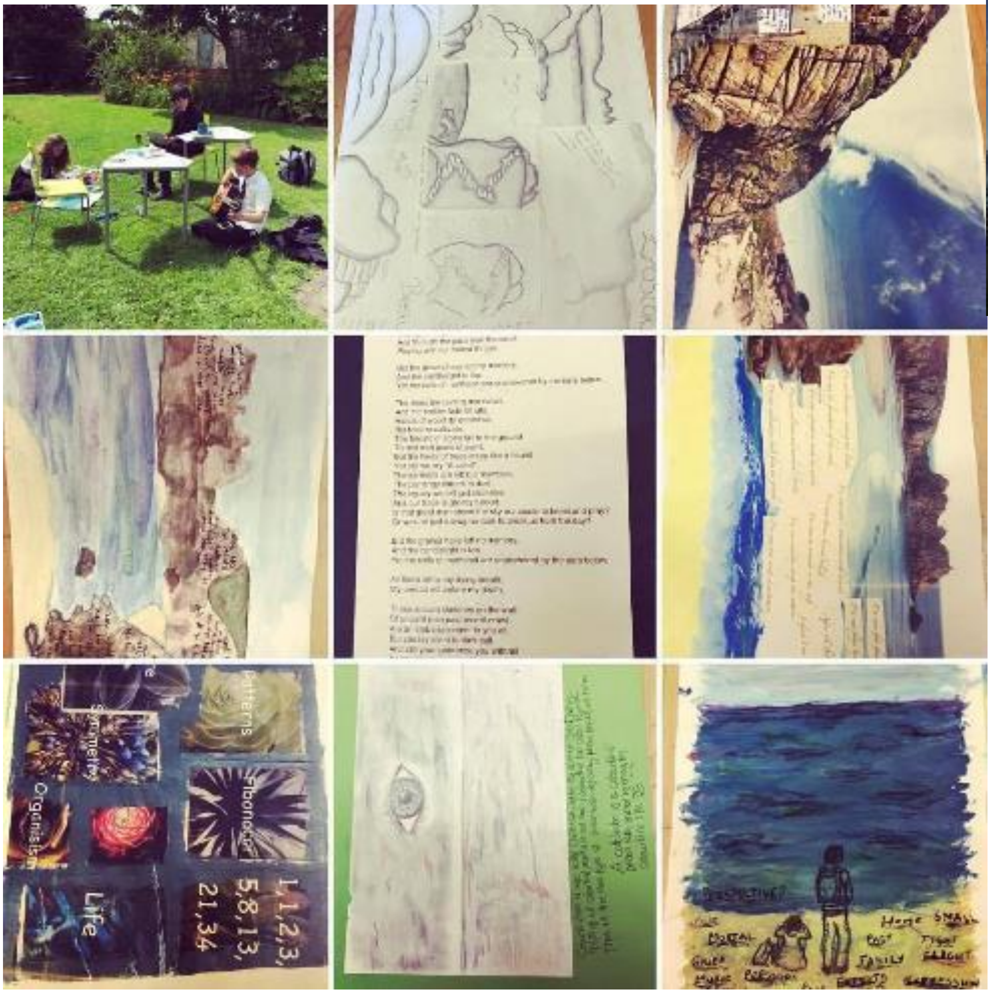
				music, play, film etc
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Prepare and then present their work in progress. Plan some questions to ask.	Teacher arranges a work in progress session for guest practtioners to return and lead a Q&A Film the presentations and Q& A	Phase 6: Present their work in progress to teachers and guests
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as	Performance, Presentation or Exhibition of the completed work	Invite parents, teachers and other schools to	

REFLECT: students reflect on the inquiry process and their learning	that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Workshop led by an interdisciplinary practitioner to produce an overture or finale that combines skills and core concepts for all to be part of Workshops led by the investigators to guide primary or younger students through an exploration similar to their own.	attend the Wild Day. Observe, document and set up quesitonairres for investigators and other participants	

6. Additional Information

The students' investigations were centered around and triggered by a Workbook – an example of which is shown below. The images below show students within the process of their investigations as well as some of their outcomes.

CREATIONS has received funding from the European Commission HORIZON2020 Programme


Life
1,1,2,3,
5,8,13,
21,34


St Michaels Mount

7. Assessment

Online CREATIONS standard students' and teacher's questionnaires.
The project also additionally used student and teacher qualitative interviews, photography, field notes and observations.

The booklet also included questionnaires before and after the project which were quantitatively analysed. The journal entries and words used in the booklets were qualitatively analysed using a set of coded language to look for and keep record of.

8. Possible Extension

An example: This demonstrator has been developed into a project week activity which also incorporates the Global Science Opera project within the week.

This came from students expressing an interest in the project being on going, like a portfolio project and this is being considered by the Arts Award leaders at the school as well as a way for students to get 'colours' through extra curricular projects. This summer, science and arts teachers have decided to plan two projects for 2018.

Summer term Cycle 1: Mind The Gap, looking at the environmental and psychological factors that affect groups of people in society. Working with homeless charities and psychologists to help students to put themselves in the shoes of others

Autumn term Cycle 2: Micro plastics and Penzance unwrapped. Students can explore a line of enquiry about micro plastics and their home town, to develop awareness and activism art work.

9. References

D3.2.21. PSCA-Inquiry Through Science & Art

Project Reference:	/H2020-SEAC-2014-1 , 665917	**Author:** **Richard Read, Cathy Palmer, Kerry Chappell**	
Code:	D 3.2. 21.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science / Arts

1.2 Type of Activity

Educational Activities based on Creativity-enriched Inquiry-Based Approaches (school based)

Local

1.3 Duration

12 sessions of 1hr 10 mins in length across a 3 month period

1.4 Setting (formal / informal learning)

Formal learning within curriculum time

1.5 Effective Learning Environment

Arts-based

Dialogic space/argumentation

2. Rational of the Activity / Educational Approach

2.1 Challenge

There were two main challenges here. The first was the fact that it is not always clear how the arts can meaningfully provide the context for learning in the sciences. Many arts practitioners might see it as a pedagogical challenge to 'use' the arts in this way to improve engagement in science, so the issue is about how to create a productive relationship between disciplines in order that science engagement develops and the arts process is also fully engaged with along the way. The second challenge lies in students' perceptions about the identity of scientists. Students can perceive scientists to be white-coated and gender-stereotyped, causing issues for which students can identify with the idea of being a scientist and for some, curtailing their career aspirations.

2.2 Added Value

The added value of the demonstrator is that it directly engages students in conversations about the relationship between disciplines rather than teaching disciplines separately around defined 'bodies of knowledge'. Through the demonstrator students engage with the process of inquiry through the lenses of a scientist and an artist and are encouraged to reflect on the similarities between the two and to understand other ways in which disciplines can interact to better engage students in learning of different kinds. The demonstrator also adds value as it directly deals with students' perceptions of who scientists are and what kind of work they do and how the learning process and inquiry through making is broadly the same. This developed understanding of scientists per se adds to students' engagement because they can better identify with the subject area and its professionals.

3. Learning Objectives

3.1 Domain specific objectives

- *Get students interested in science and research through autonomous inquiry*
- *Immerse students into our school's pedagogical approach to studio based learning and inquiry through making*
- *Get students to reflect on their perceptions of what being a scientist and an artist means to them and the similarities between the two.*
- *Students move away from a white-coated gender-stereotyped view of a scientist*
- *Teach students how to develop a creative approach to learning, relevant to a scientific topic*
- *Bring subjects closer together through an interdisciplinary approach to project based learning*

3.2 General skills objectives

- *Active participation in the negotiation of scientific concepts*
- *Develop creative and critical skills*
- *Understanding of scientific concepts and phenomena*
- *Scientific interconnection of science with art*
- *Develop cooperation and teamwork skills*
- *Develop their ability to lead their own inquiry in order to answer a driving question*
- *Students and staff develop their awareness and competence at managing a project across subjects and studio spaces*

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the Demonstrator is to give secondary students the opportunity to work across the arts and science in order to create a meaningful context for learning, and for them to understand the other relationships which might exist between Science and the creative approach to learning, which is naturally associated to the creative arts. The Demonstrator also aims to develop students' perceptions of what it means to be a scientist and an artist. The idea being that as their perceptions develop they are more likely to associate "being a scientist" with the school's general approach to learning in any discipline, and therefore be more motivated, confident and curious to learn about science using a creative approach common across all disciplines. Students can clearly see how the experimentation approach to art, which is often seen as more playful, open and exploratory, applies equally to Science and that Science is not about being right or wrong and "knowing everything." The concept of discovery in both art and science is underpinned by not knowing, and a curiosity to explore the unknown. The Demonstrator may not set all students on the pathway to being a scientist but it will hopefully engage those not interested in a scientific career in a more civically engaged way as adults.

4.2 Student needs addressed

Year 7 students (11-12 year olds) arriving into school need to be supported to adapt to the school's pedagogical approach to studio-orientated project based learning. Most will be leaving a primary school Year 6 experience heavily focused around standardised testing and many students often feel like they "don't learn anything" when they arrive because the focus on learning is so different. Our Key Stage 3 approach is centred around what "being the…" means in different disciplinary areas, rather than building a body of content for an isolated curriculum area in order to pass a test. Students often struggle to engage with their learning in Science through an exploratory and creative approach, often afraid to experiment based on a perception of getting it wrong.

5. Learning Activities & Effective Learning Environments

Science topic: The scientific method (a process of inquiry through making) (Relevance to national curriculum) Class information Year Group: 7 Age range: 11-12 Sex: both Pupil Ability: Extremely mixed	**Materials and Resources** *What do you need? (eg.* printed questionnaires, teleconference, etc.) Time for staff to plan in interdisciplinary teams. Online learning platform for students to access learning easily across subjects. Open-minded approach to the outcomes of students. Awareness of the objectives being focused on the process of learning rather than the outcome. ***Where will the learning take place?*** *On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?* Science laboratory Design and Technology studio Art & Humanities studios ***Health and Safety implications?*** Required continual review based on the development of students' own projects ***Technology?*** Access to digital devices (including students' own devices) was vital for accessing our online learning platform within all studios ***Teacher support?*** All groups of 30 students had a qualified teacher and a teaching assistant assigned to them. This enabled 8 adults to facilitate the learning of 120 students taught at the same

	time in Design Inquiry (Science and DT) and Art & Humanities (Art, History, Geography) lessons.

Prior pupil knowledge All students had no experience of learning in our school before the project began. Their experiences in all subjects was extremely varied across the cohort.
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* This is not applicable. The learning objectives in regards to leading their own inquiry were ongoing and prevalent throughout the project.

Assessment	**Differentiation**	**Key Concepts and Terminology**
We used a set of research and inquiry criteria to support students in reflecting on their progress through their inquiry. Formative assessment was constant throughout, using TED (tell, explain, describe) questioning to support students in reflecting on their process of inquiry as individuals and a team. Key art and science specific skills/criteria relevant to specific	*How can the activities be adapted to the needs of individual pupils?* This occurs through the project being pupil-led	**Science terminology:** Not applicable as remit so open, different terminology emerges for different students **Arts terminology:** Not applicable as remit so open, different terminology emerges for different students

projects and inquiry (e.g. variables, hypothesis, painting techniques etc.) were assessed alongside students.		

Session Objectives:

This is not applicable. The learning objectives in regards to leading their own inquiry were ongoing and prevalent throughout the project.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design	Engage with teacher's questions. Meet with and listen to visiting professionals' informal presentations about their careers in Arts and Science, asking	Will use challenging questions to attract the students' interest and spark their curiosity. TED (Tell, Explain,	Students did conceptual drawings of what "being the.." looked like in different subject areas.

	and collaborative work, as well as in the initial choice of question.	questions and being curious. Plan a series of tests in order to identify a mystery substance (egg white) to model the process of inquiry (scientific method). Students develop their own driving questions in relation to a wider theme (4 options given) to support their individual/group inquiry.	Describe) coaching questions to support students to develop their awareness of what they are doing and why.	Playing and experimenting with paints and colour with a "what happens if?" approach rather than led didactic teaching with predetermined outcomes.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Risk, immersion and play Students have to share with the group what they believe the	TED (Tell, Explain, Describe) coaching questions to support students to develop their	Students regularly had to evidence how their inquiry was developing across all

		mystery substance to be and the evidence they have collated to prove this. Students empowered through group critiquing when sharing their discoveries of paints and colour.	awareness of what they are doing and why. Supporting students with a conducting, choreographing or coaching approach dependent of the needs of the learners.	subjects through sharing and group critiquing. This informed next steps in their individual inquiry. The main making in art was through experimentation with various materials and students created their own responses relevant to their own line of inquiry.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analysed data in relation to the speed of drying paint in different conditions in one of the areas of inquiry offered.	Supporting this process with writing frames to model the scientific method/process	Analysis through group art-based critical responses to outcomes.

			of inquiry and analysis.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	In all areas students build a body of research (in a variety of guises) to help them answer their driving questions.	TED (Tell, Explain, Describe) coaching questions to support students to develop their awareness of what they are doing and why.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Some students related colour pigments, environmental conditions and colour theory to help explain why paints dry at different rates. There was no distinct separation between	TED (Tell, Explain, Describe) coaching questions to support students to develop their awareness of what they are doing and why.	

		Art and Science at this point and their inquiry was continuous through both subjects' lessons. Some students were able to explain what the mystery substance was based on their developed knowledge of chemical properties of egg white.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Exhibitions at the end of the term provided the platform for students to share their inquiry with students, teachers and parents.	TED (Tell, Explain, Describe) coaching questions to support students to develop their awareness of what they are doing and why.	Analysis through group art-based critical responses to outcomes.

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students did conceptual drawings of what "being the.." looked like in different subject areas. Written evaluations of their project, reflecting on the success of their inquiry and identifying next steps for leading inquiry in this way.	Analysis of drawings to look for shifts in perceptions.	Students did conceptual drawings of what "being the.." looked like in different subject areas. Group critiques

6. Additional Information

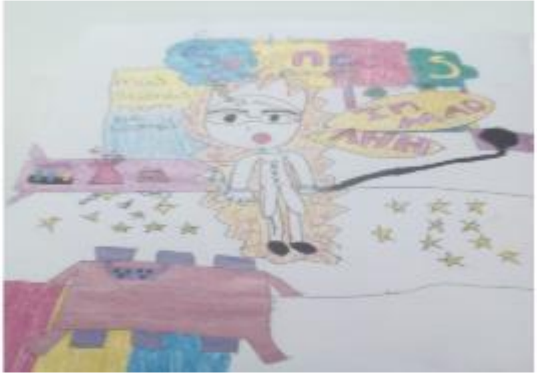
The students' investigations were centred around and triggered by the following driving questions:

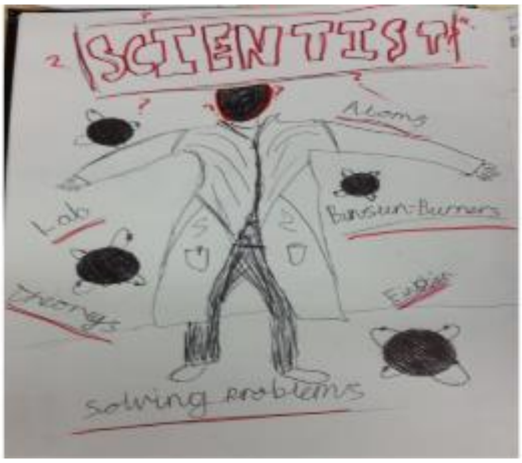
How do I connect to the Sea?

How long does it take paint to dry?

What's the solution to plastic pollution?

The images below show students within the process of their investigations as well as some of their outcomes.




SCIENTIST
Atoms
Lab
Bunsen-Burners
solving problems


Scientist
Problem solving
Tests
Math
Logic
Facts

7. Assessment

Online CREATIONS standard students' and teacher's questionnaires.

The project also additionally used student and teacher qualitative interviews and conceptual drawings.

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8. Possible Extension

9. References

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D3.2.22. Inquiry based Visual Projects using Photography

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** **Liz Rae, Jacquie Olsen and Lindsay Hetherington**	
Code:	D 3.2.22	**Contributors:**	
Version & Date:	**Version 1 16/2/18**	**Approved by:NKUA**	

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1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science (any science topic may become the subject of this activity. In this case, the topics used included magnetic fields; chemical reactions; sound).

Photography – the activity develops photographic skills such as composition; manipulation of images; impact of adjusting the technology (e.g. shutter speed).

1.2 Type of Activity

Educational Activity based on creativity-enriched inquiry based approaches (school based local activity)

The project consists of the creation of photographs of a variety of science activities designed to engage students and encourage them to question what is happening.

1.3 Duration

24 hours per week over 2 weeks – student 1 and average 1 ½ hours per week for 6 weeks – student 2.

1.4 Setting (formal / informal learning)

Formal Learning: The project was designed for use in a unit in which students who have been excluded from school for poor behaviour are educated. The flexible and adaptive nature of the demonstrator means it could be used effectively in informal learning settings or within more mainstream schools, with appropriate adaptation.

1.5 Effective Learning Environment

Arts-based

Dialogic/Argumentation

Experimentation

Inquiry based

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2. Rationale of the Activity / Educational Approach

2.1 Challenge

To engage students who have been excluded from mainstream schools. Often there has been a chronological gap in their education and they are usually mentally and emotionally 'switched off' from any formal education. The experience these students have of learning has been negative and they are often hostile towards authority and education. The challenge is to build relationships, trust and most importantly their self-esteem and confidence to re-engage in any aspect of learning. Quote from Student 1 midway through the first week of activities: "The thing I love about science is that you make loads of mess". Quote from Student 2 during a session of Science/photography: "Do you know what – if I did more stuff like this in school I would still be in mainstream school." Quote from Student 1's tutor: "his self-esteem has increased massively; he is so proud of the work he has done and wants to show people his pictures and he likes to talk about what he has been doing in the sessions".

2.2 Added Value

The main approach is to use the student's own interests and personality to develop some ideas for scientific projects that will interest them. This is done in discussion with the student, e.g. love of music translates as an investigation into "what sound looks like". These practical based projects are then recorded by the student through photography. This provides the student with a new skill and an outcome they are proud of. Through ongoing discussion during the project sessions the students express inquiry based ideas to either extend a project or explore a new area.

Students: The students involved in this project felt confident enough to return to science in a more curriculum led approach to learning. Furthermore other students saw the projects we were engaged in and immediately wanted to take part as well.

Staff: This project involving exploration of new ideas has led to acquiring new resources and using new approaches to looking at different scientific concepts – not necessarily through the conventional experimental and investigative practical methods. Other staff seeing the projects underway; the engagement of the students and also the displayed photographs were keen to use this approach to engage other students.

3. Learning Objectives

3.1 Domain specific objectives

Science-based objectives:

- To get students to engage with the process of learning in an inquiry led practical way.
- To link scientific concepts to art in a visual way.
- To encourage students to take up further opportunities to engage in science/learning.

Photography-based objectives:

- To experiment with photographic equipment and techniques with confidence.
- Allow students to take ownership of high quality work produced which promotes self-belief and confidence.

3.2 General skills objectives

- To encourage students to enjoy an aspect of learning.
- To encourage active participation in practical investigations.
- To promote inquiry and then extend projects.
- To encourage dialogue and suggest further ideas.
- To encourage responsibility for their learning.
- Positive outcomes linked to process of learning and experimentation.
- Positive outcomes linked to improved self-confidence and self-esteem.
- Enhancing the school environment with permanent visual displays that link science and photography.

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

- To engage students in the act of questioning; experimentation and problem-solving.
- To produce high-quality framed photographs linking science and art that could be displayed in the Centre. These images then to stimulate questions and promote further experimentation and problem solving.

4.2 Student needs addressed

Students (14-16 year olds) excluded from Main-Stream School often haven't been involved in Science education for several years as their behavior has precluded them from working in the laboratories because of consequential disruption and for safety reasons.

Inquiry based visual projects allow the students to engage in scientific concepts that help their basic understanding and allow them to see the relevance and wonder of science. Capturing and manipulating the photographic imagery then allows the student to take ownership of their work. Finally, seeing the resulting images displayed on the walls has positive effects on self-esteem and self-confidence and can result in a student re-engaging with more formal, curriculum-based learning.

5. Learning Activities & Effective Learning Environments

We used two students' projects in this Demonstrator which we will describe separately. Each

project was approached differently which is key to the success of this Demonstrator.

For every session the objective was for the student to engage in the activity and to produce some photographic work that they could be proud of. It is hard to put our planning into any conventional format as the methods are sometimes unplanned and have to be fluid enough to move with the mood and needs of the student on the day. It is for this reason we have described each session and assessed the success of each.

In each session hazards and risks were assessed and relevant safety precautions were taken but not itemised here.

Project 1:

Male student.

End of Year 9/beginning of Year 10

Is the subject of an "Early Health Care Plan" (EHCP). Diagnosed with Attention Deficit Hyperactivity Disorder.

Student is based at The Holway Centre where a recent group for excluded, vulnerable students has been created. Although this is part of our College it is a separate Unit so we were not familiar with the student or the facilities at the Unit.

Week 1

Day 1: (At The Holway Centre)

Resources for activites:

Making slime: Borax, pva glue and food colour. Surgical gloves; plastic cups; stirring rod; measuring cylinder and balance.

Light writing: strings of battery operated coloured fairy lights, camera and tripod.

Activities:

Met student and through dialogue, started to get to know likes and dislikes and way of working. Began to develop relationship and trust. Explained to student what the Creations project is and what it could mean to him. Completed student questionnaire. Simple practical activities planned:

Making slime: Student encouraged to measure volume and mass; followed instructions to see a chemical reaction. (Higher level - idea of molecules lining up into long chains of polymer). Taking pictures of the strings of slime as they formed. Student explored the properties of the slime as it transformed from a fairly viscous liquid to a piece of bouncy putty.

Light writing: Student experienced the "magic" of photography using a technique away from the usual conventional pictures that are taken. Used moving lights in darkened room and camera on tripod with slow shutter speeds to "write" student's name in lights.

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Used album of exemplar photos to develop some ideas for projects to investigate for the remainder of week 1 and to plan the necessary resources to take with us on each day.

Assessment:

Level of engagement excellent with plenty of ideas for the remainder of the project. Activities kept simple and were effective at engaging student. Student really enjoyed using the camera and talked about taking photography further to GCSE.

Day 2: (At The Holway Centre)

Resources for activities:

Boiled egg in a conical flask. Extra eggs; conical flasks and matches for student attempt.

Density tower: Liquids of different densities: pva glue; golden syrup; washing-up-liquid; milk; water; vegetable oil; food colour. Straight sided tall glass; plastic cups; measuring cylinder; spoon; funnel; pipette.

Black and white striped A4 or A3 sheet to show refraction through density tower.

Extended work on density: Alka Seltzer tablets; water; vegetable oil and inks.

Activities:

Student chose images from yesterday's light writing to create his name – mounted on black card for display – immediate positive results.

Egg in a conical flask: challenged student to come up with some ideas how it got there. Encouraged problem solving by applying scientific concepts of pressure. Student encouraged to perform the "trick" himself.

Introduction on how to use the camera for close ups and film.

After quick explanation of density student introduced to the idea of a density tower. Encouraged to problem solve on how to introduce the separate layers gently and in what order; how thick should the layers be to allow them all to fit in the glass? (student chose to use a ruler rather than measure the volume of the liquids).

Student encouraged to take close up abstract pictures of different layers within the tower as well as the whole tower.

A second glass of oil and water was then used with a striped black and white background behind it to take some pictures of the distorted patterns produced. Link to refraction. Dropped Alka Seltzer tablet in glass – took pictures of bubbles through water and oil and linked the science as a chemical reaction and a gas being produced – bubbles.

Through student led enquiry and engagement went on to take photographs outside using different camera techniques. Throughout the process discussions and dialogue led to further planning to include student's love of scootering.

Assessment:

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Use of unrelated visual activities kept interest levels up (equivalent to short "chunks). Excellent level of engagement – helped by being able to experiment and pick up on things as they are discussed. Using the student's interest to guide the learning experience resulted in a very positive experience for the student. Student said he definitely would like to carry on with the project beyond this first week. Student looked exhausted by the end.

Day 3: (At The Holway Centre)

Resources for activities:

Elephant toothpaste: Potassium iodide; hydrogen peroxide; washing up liquid; splints; matches; plastic bottle; funnel; measuring cylinders.

Coin in the cup: white plastic cup; coin.

Cyanotpye photography: light sensitive paper; developing chemicals.

Density "mash-up": water; oil; shaving foam; Alka Seltzer tablets; glitter.

Activities:

A day extending themes previously looked at:

Chemical reactions: "elephant toothpaste" – violent reaction creates "wow factor" – heat given off/ fizzing and tested the bubbles for oxygen – more "wow factor" as bubbles rekindled the glowing splint. Allowed more discussion around chemical reaction and talked about the difference between chemical and physical change. Filmed the reaction on his phone – allows student to share with others.

Refraction - Coin in the cup: now you don't see it – now you do! Science magic – received very well – another way to explain refraction. Student wanted to show this trick to his tutor the following day.

Cyanotpye photography – outside to collect foliage to make cyanotype prints – a break and fresh air and encouraged thinking about the types of form that would create good shapes. Back inside to develop the pictures and engaged in thinking of other ways to create images (writing on the paper).

Photography session outside using scooter as subject of the shoot. Encouraged student to think about composition in unusual and creative ways (scooter in a tree; contrasting backgrounds). Dialogue with student led to discussion around the student taking GCSE photography.

Back inside and set up a glass vase with water oil and shaving foam- talked about whether foam is a liquid, gas or solid (listened to the liquid in the can before squirting it out – prompted discussion about pressure). Dribbled inks down through the foam – inks finding the path of least resistance through the bubbles. Drops of ink kept their bubble shape through the oil and then spread and diffused through the water. Talked about immiscible liquids and different densities – mentioned hydrophobic and hydrophilic molecules. Talked about process of diffusion. Student taking film of processes with camera and his phone.

Session spent looking at images from previous day and selecting some for display/ for his photo book.

Assessment:

Student very tired at beginning of session. A very full and varied session – again guided by the student's interest and level of engagement. The photographic outcomes have definitely impressed the student and boosted his self-confidence – saying again he would like to take GCSE further.

Day 4: (At The Holway Centre and the local skate park).

Resources for Activities:

Framed photos student identified from previous sessions

Zoomy (hand-held) digital microscope.

Camera and sunflower.

Activities:

A complete change from the topics of first 3 days – focussing more on the photography using different magnifications – down to taking pictures with the Zoomy hand held microscope of fruit and things around the room.

Hung up framed photographs in the main corridor. This display of photos allowed the student to show visitors and his mum work that he was very proud of and explained how he achieved them.

Took close-up photographs of a sunflower to use in a Gala Arts Evening to be held at the Holway Centre in aid of the local hospice charity (sunflower is the emblem of the charity). Student was confident in using camera and remembered how to use "depth of field". Photograph framed and presented to the Charity.

Visited local skate park where we took photos of student in action on scooter.

Completed end of week one questionnaire and discussions about possibility of continuing the CREATIONS project for a second week in September. Student keen to carry on. This prompted suggestions for different topics that might be of interest. We agreed to include a day trip out to Minehead where we could take photos on the beach and of the student in the indoor skate park and also for the student to visit our Centre (Pupil Referral Unit for 14-16 year old students) where he could access more science and photographic equipment.

Assessment:

Positive response to end of first week. Questionnaire by student shows overall success of project in terms of engagement and boost to self-confidence and self-esteem. Very positive comments from student's tutor. Student keen to show photographs on display to Mum and other staff members. Framed print of sunflower presented to Hospice also a source of positive self-esteem. Student has said he would like to complete a second week of activities in September.

Second week

Day 1 (Holway Centre – in classroom and outside)

Resources for Activities:

Fire writing: Sodium nitrate and filter paper/blotting paper; splints and matches.

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Holograms: i-pad; homemade Perspex square based pyramid to create holograms using i-pad App.

Activities:

Catching up; chatted about what the student had done during the Summer holiday and re-established relationships. Discussed what we could do this week. Agreed day visit to Minehead beach and Skate Park. Made suggestion of what scientific projects he might enjoy. Agreed visit to other Centre to use different equipment; visit was also to encourage confidence in unknown surroundings and meeting new people.

Showed student some exemplars of fire writing and using video and fire triangle went over what is needed for fire. Using Sodium nitrate – talked about solutions and saturated solutions; what sodium nitrate is made up of – looked at chemical formula on bottle and made link to Periodic Table – what elements it contained and the number of atoms of each in a molecule of the compound. Made the link that it is the high number of oxygen atoms that feeds the fire. Also talked about the hazard symbol and what oxidising agent means and the safety implications. Student then had to design a pattern to paint with the sodium nitrate solution with the idea that the pattern needed to be joined up and without holes. Repeated using different designs; student learning from his mistakes each time. Student needed to take responsibility for the safety of burning materials – outside/sheltered/not too close to any buildings. Student took film of the burning once it had got underway.

Moved back inside and looked at holograms using i-pad, hologram App and Perspex square based pyramid. Engaged by this – a possibility for further investigation – possibility of creating a hologram of student.

Assessment: Good re-engagement and attitude towards the remainder of the project. Complete immersion in the fire-writing activity and showing resilience in learning from mistakes and trying different approaches for success. Responsible attitude towards using matches. Good start to the second week.

Day 2: (Student to Pupil Referral Unit – new environment – people and place).

Resources for Activities:

Fire writing follow up: pre-prepared paper with student's name written on with sodium nitrate solution and dried; fume cupboard; matches and splints.

"Seeing sound": Large loud speaker covered in cling film; connections to amplifier and computer or mobile phone (music source); cornflour paste; food colour; coloured sand; beads; glitter; feathers; polystyrene balls; CD; paper clips etc. – things that can be put on the speaker to see movement.

Magnetism and ferrofluid: selection of magnets (including neodymium); iron filings (coarse and fine); compasses; ferrofluid; inks of various colours; glass sheet; plastic peg to hold magnets; iron nail/screw; large magnet taken from an old loud speaker; surgical gloves.

Activities:

Fire writing using prepared sheet with student's name on. Burned it using fume cupboard (student not familiar with fume cupboards – explained what it did). Paper burned too vigorously and whole sheet burned away. Talked about what the black stuff that remained was and how we could use it for drawing. (Higher level – talk about structure of graphite).

Discussed with student what he would like to do first – sound or magnetism – selected sound.

Student helped set up sound system with speaker, amp and computer. Chose which material he wanted to put on the speaker (blue sand) and selected music with a good beat. Took pictures of the sand "dancing" on the speaker. Moved on to using cornflour paste and then with wooden beads and glitter mixed in with the paste and food colour. Student enjoyed playing with the cornflour paste with his hands (looked at video of people running across a tank of non-Newtonian fluid). Went on to take photos of feathers; polystyrene balls; a CD and paper clips on the speaker.

Watched You Tub video of "Slo Mo Guys" showing paint on a speaker https://www.youtube.com/watch?v=5WKU7gG_ApU (WARNING – some swearing). Explained the science behind it – vibrations and particles and why there is no sound in space. Louder, lower pitch sounds translate as bigger movements in the speaker.

Through natural enquiry and through dialogue moved on to investigate mixing different coloured paints – ended up with green which prompted a conversation about photosynthesis.

Student not in a position to move on to look at magnetism.

Assessment:

Student had had a bad morning before school started – very nearly didn't make it into school.

Very positive outcome considering the difficult start and unfamiliar surroundings and people. Student reacted positively to the new people he was introduced to and the new environment. Student had taken some excellent shots – particularly of the speaker. Student grasped the idea of sound being vibrations and why there is no sound in space.

Magnetism with ferrofluid can be used as a future activity.

Day 3: External visit.

Resources for Activities:

Beach: suitable clothing and footwear; bag to collect interesting specimens; camera.

Minehead Eye skate-park: student's own scooter; helmet; protective clothing; camera.

Activities:

Drive to Minehead. Parked and short walk to beach. Began with student taking pictures of headland; beach and panoramic shots - working out how fast he needed to move the camera to get 180°. Throwing stones into the sea (no-one else on beach so no health and safety issues) – large stones and skimming stones – thinking about what shape makes a good skimmer stone. Tried to take photos of the large stones as they hit the water. Looked at seaweed on the tide line – how it is adapted to float on the water with air pockets so it can get enough light for photosynthesis. Picked up some interesting stones (colour); glass; shells; bone. Began to rain – all amazed by the indentations left in the sand by the rain drops – took photos. Looked at the rocks at the top of the beach and talked about how they got there. Student took close up photos and fully engaged listening to how the quartz veins; sedimentary layering and fossils formed within these rocks. Talked about the conditions that would have existed on Earth at

the time the rocks were formed and how sedimentary layers with smaller stones and shells might have been embedded. Picked up bits of plastic rubbish on beach and talked about pollution in the sea. As we left the beach, plants growing on the edge of the sand prompted another conversation about adaptation to living in salty/sandy environments. Took some photos in the amusement arcade – student exploring with creativity in composing shots with mirrors and bright colours. Steam train on platform as we walked passed so took some shots of the engine. Returned to the car park to collect scooter and helmet and then to skate park to have lunch, chatted and discussed action shots in photography. Skate park empty so we were able to go in to the park with student and take some action shots of the stunts and jumps. Student encouraged to come up with ideas for good shots – in action and stills using scooter and skate park surroundings (graffiti etc).

Overall Assessment:

Through engagement in the activities and learning – an excellent day. This natural way of learning in the environment clearly suited the student – shown by his total engagement. Relating the Science to what could be seen and felt in the environment was very successful. Some unexpected learning opportunities taken up and some for possible extension activities: e.g. wave action; zonation of shoreline; physics of throwing; steam trains; pollution.

Day 4: (Holway Centre)

Resources for Activities:

Computer to access photographs; camera; hydrochloric acid (1M); specimens picked from the beach yesterday; final Questionnaire.

Activities:

Chatted about the trip yesterday – enjoyed. Looked through printed photos so far – agreed to add titles and labels. Looked at Minehead photos on computer and selected more photos for printing; some to take home to show Mum and some for the photobook.

Revisited rock formation and then used hydrochloric acid to test for limestone on a sample of limestone and then tested the rock samples we had collected on the beach. Talked about why limestone fizzed. Tested limpet shell - reacted violently – discussed how this links with limestone.

Completed final Questionnaire and talked about his experience with the project.

Assessment:

Engagement very positive – today and through reflection on the whole project. Student has expressed interest in taking GCSE photography. The work he has completed so far could go towards an Arts Award. Student recommends this way of working to others. Student felt the project had been of benefit to his Science learning although couldn't articulate how.

Project 2

Male student aged 15.

Year 10/11 student on roll. Student who we identified as a student who had removed himself completely from all forms of learning and engagement in all activities.

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This approach was not so structured because the student attends the Centre so we could design activities at times to fit in with the rest of his time in the Centre.

The student was encouraged to engage in the project through love of music - showing the student previous attempts to photograph images of cornflour paste on a loud speaker.

All the activities took place in the Centre – in the Science or Art room.

Session 1:

Resources for Activities:

Questionnaire

Exemplar book of photos

Activities:

Student completed the Questionnaire and we had a discussion about what else he might be interested in using the book of exemplar photos (including the cornflour on a speaker photos).

Assessment:

Student engaged in completing Questionnaire with some thought but not too interested in thinking about other topics that might be of interest at this stage. Happy to start with the "Seeing Sound" at the outset and see where this leads.

Session 2: (Another student joined in with this activity as a way to encourage the student, who is subject of the study, to join in).

Resources for Activities:

Seeing Sound: Guitar (or any musical instrument); Loud speaker (covered in cling film) connected to amplifier and student's mobile phone; cornflour paste; liquid soap; various materials to bounce up and down on the speaker; slinky.

Activity:

Used guitar to demonstrate and explain how vibrating strings create the sound. Discussed why there is no sound in space.

Students worked collaboratively together to produce some excellent images of different materials on a speaker. Student mainly engaged in finding different music to experiment with the effects on the speaker but this led to engaging in suggesting ideas of using different materials to go on the speaker.

Student would not engage in taking any of the photos – the other student took the photos.

Went through movement of longitudinal wave using slinky and compared it with transverse wave form.

Assessment:

Although student took a back seat initially it gave him the confidence to engage in the experimental process in his own time at his own pace. Not interested in taking any of the pictures or film of the action. Other student took some good photos which both students appreciated. Not interested in the slinky demo. Difficult to gauge how this session would have gone without the other student joining in.

Session 3: **(continuation of seeing sound topic – student working on his own)**

Resources for Activites:

Seeing sound: round and square Chladni plates; vibration generator connected to signal generator; salt; coloured sand; "hundreds and thousands"; computer to show sound wave animation.

Activities:

Started with small bit of theory on longitudinal wave form and frequency. Used the signal generator to create patterns in salt; coloured sand and hundreds and thousands on the square Chladni plate. Student reluctant to engage in taking photos initially but he was persuaded through cajoling and good humour. Engagement lasted about 15 minutes – enjoyed seeing the patterns as they emerged. Experimented with the volume control on the signal generator – saw sand bounce off the plate when it got loud.

Assessment:

Short period of engagement good but struggled to continue. Student struggling with poor emotional health; drug abuse and level of concentration. Unsure how to continue. Decided to spend time talking with student to explore other options for topics to explore.

Session 4:

Discussed options with student and encouraged him to explore options for himself using You Tube – amazing Science experiments videos to stimulate interest. He came up with the idea of oil/water/ink and bicarbonate of soda in a wine glass. Wanted to work with friend (same student he worked with on the loud speaker - session 2).

Session 5: **(working with another male student – same as in Session 2)**

Resources for Activities:

Wine glasses; oil; water; coloured inks; sodium bicarbonate; Alka Seltzer tablets.

Student recalled concept of density at the start. Students working independently – experimenting with the effects produced as different coloured inks dropped down through the oil into the water and then adding sodium bicarbonate and in further attempts – Alka Seltzer tablet. Student not keen to take photos initially but once the other student had taken some he was happy to use the camera confidently. Went on to take photos of water and oil with a black and white background. Student completely engaged in getting the background lined up so that the black and white background appeared as quarters. Discussed the concept of refraction and the getting the angle of refraction just right to get the desired effect for the photo.

Assessment:

Considering the previous lack of engagement this session was very successful. A combination of being responsible for his learning (having chosen the activity) and working with a friend gave the student confidence and importantly he enjoyed the session. Boost to self-confidence and self-esteem.

<u>Session 6:</u> (5 days after last session - not planned as a CREATIONS session but student asked to do some Science).

<u>Activities:</u>

Looked at Group1 metals in water. Student happy to follow instructions and taking full safety precautions, cut up pieces of the metals and dropped them in a trough of water. Through discussion of what was going on we moved on from this to think about pH and tested the pH of the water from the trough in a spotting tile with Universal Indicator. Compared this with the colour produced when 1M Hydrochloric acid was tested. Then tested random solutions around the centre (soap; sink cleaner; lemon juice etc.) Took photos of the spotting tile after we had labelled what the spot tests were.

<u>Assessment:</u>

A big step forward for the student. A morning spent enjoying learning Science and most importantly having the confidence to engage.

* In a session after the CREATIONS project had been drawn to a close the student created a rainbow of pH using different concentrations of acid/alkaline.

<u>Session 7:</u> (Student requested to work with ferrofluid).

<u>Resources for Activities:</u>

Ferrofluid; different coloured inks; selection of magnets – including neodymium magnets; iron filings; glass sheet; peg (to hold magnet); petridish (to hold ferrofluid).

<u>Activities:</u>

"Played" around with magnets – attract and repel; used paper and iron filings (coarse and fine) to look at magnetic field patterns. Went on to introduce ferrofluid. Patterns produced in the ferrofluid by the presence of 1 and 2 neodymium magnets - student described as "pretty cool" and inspired him to take some close up shots of the patterns before and after introducing coloured inks into the ferrofluid. Took some excellent photos.

<u>Assessment:</u>

This turned out to be the student's most successful experience resulting in the production of some amazing images which he continues to refer to. Improved confidence.

<u>Session 8:</u> (Unplanned and worked with another male student)

<u>Resources for Activities:</u>

Large fish tank of water; wax; heat source; saucepan; syringes

<u>Activities:</u>

Student and another male student came in wanting to do some "fun Science" and through some discussion decided to play around with wax and water. Both students happy to do some revision theory

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first on solids, liquids and gases and change of state. Heated wax and dropped it into a tank of water. Solidified on contact with the cold water and created some interesting shapes on the surface. Taking pictures as wax hit the water and then of wax formations formed. Talked about density and some good debates about how we could get the wax to travel down further to form vertical columns into the water – would rely on the wax not solidifying so quickly? Changing temperature of the water? Or using something other than water? Or finding a way to squirt the wax down into the water. Quote from student: "Do you know what? If I did more stuff like this in school I would still be there – I'd still be in mainstream".

Assessment:

In this instance the CREATIONS student was more settled in the learning process and he was the one to take control of taking the pictures of the patterns in the wax.

For this student the CREATIONS project has led to them engaging in more formal curriculum based learning as well as enjoying ongoing projects linked to photography. He has many photographs displayed around the Centre and these are a constant source of personal pride.

The improvement in his emotional health, self-confidence and self-esteem has improved his attitude to learning across all subjects and he has recently taken a Functional Skills Maths exam.

Science topic: Developed following discussion with small group of pupils to explore their own interests (Relevance to national curriculum) Class information Year Group: Year 10 or 11 Age range: Aged 14-16 Sex: both Pupil Ability: Can engage pupils with a range of abilities, but pupils are all disengaged with learning having been excluded from school	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Camera, scientific inquiry materials relevant to pupil interests** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Science laboratory, off site visits* *Health and Safety implications? Risk assessment of different activities required* *Technology? Dependent on pupils' interests.* *Teacher support?*

Prior pupil knowledge: Dependent on choice of science topic relating to pupil interests.
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will be coached to produce high quality photographs based on scientific inquiries conducted in response to their own interests.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Informal teacher observations		

	How can the activities be adapted to the needs of individual pupils? This is a highly adaptive approach, focused on the specific needs of individual pupils.	**Science terminology: This is dependent on the choices made by the teachers in response to the students' interests.** **Arts terminology: shutter speed, exposure, contrast**

Session Objectives: To be developed responsively by teachers. During this scenario, students will

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	Engage with teacher's questions and ask their own.	Will use a provocative scientific context to encourage pupils' questioning	

	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Experiment with the inquiry materials, encouraged to propose suggestions for what is happening and why, and what would be interesting to photograph.	Offer encouragement	**Creating artistic photographs that also document observations**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Analyse what photographs show scientifically and what makes them good quality art work	Support and scaffold	

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Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.Students use photographs as a prompt to develop their own explanations of what they have observed and recorded through their photography.	Writing frames, scaffolding and questioning.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students discuss how their ideas and explanations can be related to scientific knowledge and explain how the photographs and the science are related to each other and give different insight into how they know what they now know.	. Prompting discussion, offering scientific explanations to link to photographs.	
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the	Teachers and students work together to choose which photographs to	Teachers and students work together to	**Creation of photographic display or book to**

COMMUNICATE: students communicate and justify explanation	scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	display, why, and how they are related to the scientific content.	choose which photographs to display, why, and how they are related to the scientific content.	**communicate ideas.**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Use a What Went Well/Even Better If framework to consolidate and reflect on the ideas developed and the quality of the art work generated and shared.	Provide support for pupils' reflections.	

6. Additional Information

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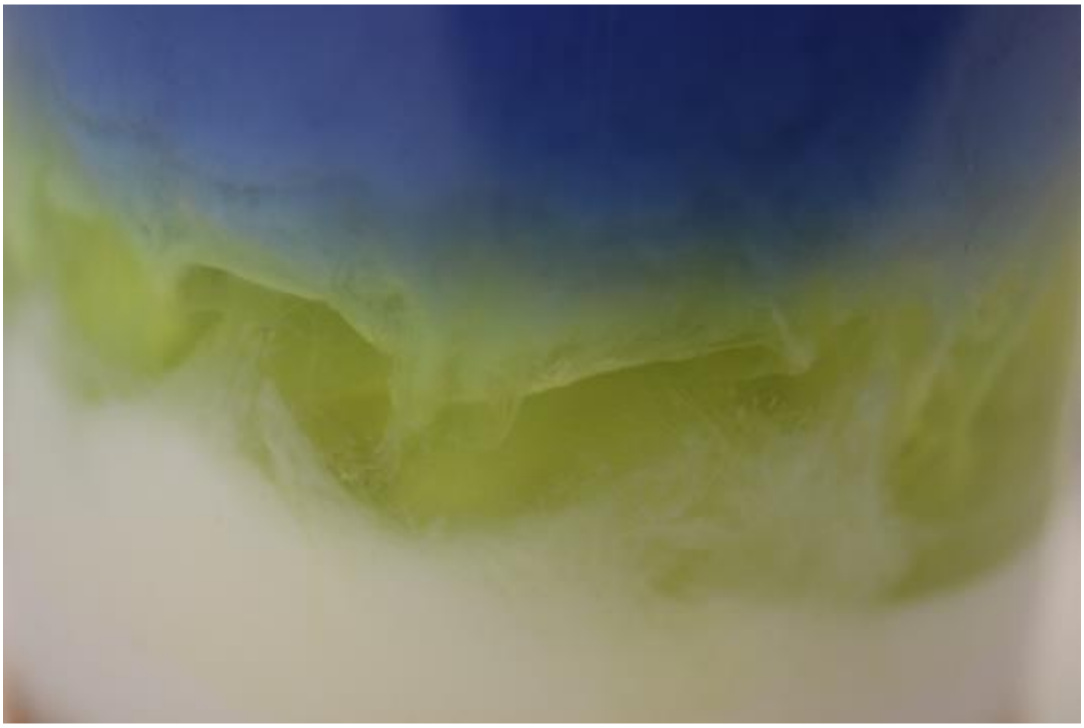

7. Assessment

Student questionnaires.

Key worker questionnaire.

Activity log by teachers.

Verbal feedback from students.

CREATIONS student and teacher questionnaires.

8. Possible Extension

- To include mindfulness activities with and environmental focussed project through visits to local nature areas (beach, woods, moorland).
- Encourage awareness of sustainability issues facing the planet through work involving plastics (using plastic generated within the centre to create an art installation and possible beach clean).

9. References

Colucci-Gray, L., Burnard, P., Cooke, C., Davies, R., Gray, D., Trowsdale, J. (2017) Reviewing the Potential and Challenges of Developing STEAM Education through Creative Pedagogies for 21st Century Learning. *A Report from one of the BERA Research Commissions*. London, BERA.

D3.2.23 Shoal of Fish

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Hermione Ruck Keene Tracey Holmes
Code:	D 3.2.23	**Contributors:**	
Version & Date:	**Version 1, 6.9.17**	**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Biology/Visual Art

1.2 Type of Activity

Educational Activities based on Creativity-enriched Inquiry Based Approaches (school based local activity).

The project consists of the creation of an artistic representation of a shoal of fish

Duration

6 hours over 3 months

1.3 Setting (formal / informal learning)

Formal learning

1.4 Effective Learning Environment

- *Communities of practice*
- *Arts-based*
- *Dialogic Space / argumentation*
- *Communication of scientific ideas to audience*

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Students tend to view subjects in isolation, not even transferring skills from maths to science, so linking art and science provides a challenge, which generates enthusiasm and motivation to engage with scientific content, whilst demonstrating to them that they can use knowledge and skills from one subject to inform another.

2.2 Added Value

Students: gaining enthusiasm for Science and Art. Most were more inclined towards those lessons having done the project. Feedback from students also indicated that this approach reduced the pressure in terms of assessment; they enjoyed the freedom to explore skills and develop their science knowledge and understanding in a different context. Students were also aware of the collaborative work within school and with the University of Exeter in developing this project, which gave it additional value in their eyes.

Staff: Both teachers were able to explore different ways of working and delivering lessons; assessment and learning objectives were discussed in detail. Teachers collaborated to manage use and distribution of resources, with the Science teacher exploring a less structured and predictable approach to the use of materials.

3. Learning Objectives

3.1 Domain specific objectives

- *Increase student awareness of how skills can be transferred between Biology and Visual Art*
- *Explore patterns of behaviour in animals for survival, with specific reference to shoals of fish*
- *Increase students' proficiency in handling different materials through the creation of model fish used to create a 3D mobile*
- *Engage parents with the students' learning by sharing the results of the project*

3.2 General skills objectives

- *Active participation in the negotiation of a preferred model of representation*
- *Development of problem-solving and discussion skills*
- *Development of critical analysis and evaluation skills*
- *Seeing connections between skills used in Science and Art*
- *Improved ability to collaborate in group work*
- *Enhancing the school environment with a permanent visual display representing links between Art and Science*

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The end product of the demonstrator is a 3-dimensional model of a shoal of fish, displayed in an open area of the school environment. Students researched how fish form shoals; some extended to starling murmerations through visiting a local nature reserve. Following class discussion, a simple fish was created from A4 paper which we glued to aluminium foil, using marker pens to add markings and camouflage. Fishing line was used to create drops of fish that can be hung to form a shoal.

4.2 Student needs addressed

Students work together collaboratively, discussing, analyzing and evaluating their project. They make connections between Art and Science in new ways, and are better able to understand connections between shoal behaviour in fish and survival of the species.

In the second phase of working in this interdisciplinary way in this setting, students demonstrated the ability to apply skills in a context of freedom to choose how they communicated their ideas.

5. Learning Activities & Effective Learning Environments

Science topic: Biology – Y8/KS3 programme of study: Habitats, Adaptation and Survival (Relevance to national curriculum) Class information Year Group: 8 Age range: 12-13 Sex: both Pupil Ability: Mixed including two students with a statement of specific educational needs	Materials and Resources *What do you need?* *Access to scientific papers via the internet – educational research database* *Access to published print resources* *Appropriate materials to make fish* *Where will the learning take place?* *On site, in the Biology lab* *Health and Safety implications?* *Safe use of cutting tools, fireproof materials for the final product* *Technology?* *Internet and media resources to support research* *Teacher support?* *Support from Science teacher during lessons; sessions planned in collaboration with Art teacher*
Prior pupil knowledge **No prior knowledge was required, but the students had learned about adaptation and survival, without necessarily linking the two together**	

<table>
<tr><td colspan="3">Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)
During this scenario, students will
Explore the movements of shoals of fish
Investigate ways to use a range of materials to represent fish as part of a 3D mobile</td></tr>
<tr><td>Assessment
Formative assessment through discussion (peer to peer and teacher to student)
Sketches to represent initial ideas</td><td>Differentiation
The open-ended nature of the task at this stage allows pupils to engage at different levels (differentiation by outcome)</td><td>Key Concepts and Terminology

Science terminology:
Habitats, behaviour, adaptation, survival, motion through fluid, streamlining, drag
Arts terminology:
Materials, 3-dimensional, mobile, use of space and light to enhance visual effect</td></tr>
<tr><td colspan="3">Session Objectives:
Students will develop an understanding of shoal patterns in a variety of fish species, including motivations for the fishes’ patterns of behaviour
Extension: explore murmeration patterns in starlings
Students begin to sketch and develop ideas for the 3-D representation</td></tr>
<tr><td colspan="3">Learning activities in terms of CREATIONS Approach</td></tr>
</table>

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions. Watch videos and use the web to explore shoal patterns	Use a new context for learning to inspire the students' interest in patterns of behaviour in shoals of fish	Sketching to explore fish movements
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students used a combination of media resources and a local conservation area to explore behaviour patterns	Provides access to media resources and facilitates discussion of pros and cons of different methods of representation of the individual and whole shoal of fish	Experimenting with different materials and methods of representing the fish

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Collaborative discussion in groups to apply understanding of fish behaviour to the visual represention	Facilitating and supporting discussion; enabling supportive criticality	Analysis of different materials and combinations of fish
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students are able to justify their choices for how fish are combined in the mobile, and generated creative ideas to enable them to move authentically	Further students' understanding through use of questioning to assess their level of understanding	Experimenting with different ways of combining individual fish
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students use their scientific knowledge to explain positioning of individual fish to create the whole shoal	Support discussion of links between scientific knowledge and final product	Assembling the final mobile representing the shoal of fish

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge through the construction of the mobile and discussion with parents at open evening	Teachers facilitate communication between students	Students take photographs or draw the final mobile
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect collaboratively on the effectiveness of the materials in representing fish behaviour	Teachers guide the reflection process and pose questions to further students' thinking	Students use images of final mobile to reflect on possible improvements

6. Additional Information

7. Assessment

Student questionnaires (paper based and online), teacher reflective logs, verbal feedback from students

8. Possible Extension

- Physical representation of fish behaviour in shoals through dance and/or drama
- Making individual and/or collaborative representations of specific moments of fish behaviour (e.g. a shoal under attack)
- Further exploration of mathematical models of shoal behaviour
- Use of computer programming to represent shoal behaviour through e.g. game or screensaver

9. References

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.24 Lise Meitner: The battle for ultimate truth

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** **Hermione Ruck Keene**
Code:	D 3.2.24.	**Contributors:** **Dr Kerry Chappell** **Dr Lindsay Hetherington** **Rae Hoole** **Heather Wren**
Version & Date:		**Approved by:NKUA**

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Nuclear fission in Physics, Standard form in Mathematics

1.2 Type of Activity

Local activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).

1.3 Duration

1 day Masterclass with preparatory Skype with CERN

1.4 Setting (formal / informal learning)

Informal learning

1.5 Effective Learning Environment

- *Arts-based*
- *Dialogic Space / argumentation*
- *Communication of scientific ideas to audience*

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Pupils are regularly challenged to relate the discovery process in Science to more abstract scientific contexts they are required to learn (Bennet, Lubben & Hogarth, 2007). In particular, elements that are perceived as 'dry' and requiring practice need to be brought to life and grounded to make them more accessible to a wide range of pupils. Similarly, reference to the history of science is often limited in the curriculum to relatively few key figures, who are largely white and male and thus of arguably limited relevance to pupils with differing identities (Archer et al, 2010). It has been suggested that using the concept of 'stories' can address some of these challenges (Solomon, J. 2002): The story of Lise Meitner offers a narrative that can help pupils understand difficult concepts in physics and mathematics.

2.2 Added Value

This demonstrator adds value to pupils' curricular learning in physics and maths by encouraging them to link the curriculum to historical discoveries and to current cutting edge science, thus situating and grounding the abstract concepts they are learning. Workshops for both pupils and attending teachers will draw on the pedagogical approaches suggested by the CREATIONS Features; teachers will be given the opportunity to explore the Features in their own dedicated workshop, as well as seeing them in action during facilitated workshops for pupils. Use of pedagogical methods informed by the Features will enable pupils to link their learning in Science and Maths to the real life application of these theoretical approaches, as well as learning about an individual behind their development.

Pupils will develop their cognitive skills in terms of mathematical concepts and their capacity to manipulate large numbers. They will develop communication skills through collaborative team activities around the story of Lise Meitner's life and in particular through debate about the moral and ideological challenges she faced in doing the type of science she did at the particular time in which she lived.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

Aims

- to inspire more young girls to want to pursue Physics to 'A level' and to see it as a viable and attractive option at Higher Education
- to raise public awareness, interest and engagement with contemporary physics, especially amongst girls
- Inspire and enthuse audiences, especially those not previously interested in physics.
- Develop the science communication skills of individuals, particularly physicists.
- to stimulate an interest in Maths and Physics, especially amongst girls
- with professional actors, through an episodic drama, to tell the story of Lise Meitner (1878 – 1968)
- to introduce the Maths Meitner used to explain nuclear fission
- to develop students' understanding of nuclear fission, radioactivity and sub-atomic particles
- to work in partnership with different sectors to see the programme roll out to a wider and geographically spread audience

3.2 General skills objectives

Please describe the skills that will be developed according to your demonstrator. As an example, see below:

In the context of the Meitner Day Masterclass, students' general skills objectives are:

- *Active participation in the negotiation of scientific concepts*
- *Develop creative and critical skills*
- *Understanding of scientific concepts and phenomena*
- *Understanding the process of development of scientific concepts as an interactive process, brought to life through drama.*
- *Develop spirit of cooperation and teamwork*
- *Understand to some extent how drama as an artform works to illuminate ideas and emotions*

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

In this masterclass, a relatively unknown historical figure (in this case Lise Meitner, overlooked for the Nobel prize for her work on nuclear fission with Otto Hahn, perhaps due to her gender and Jewish heritage), their background and work in science are brought to life by a creative learning company (Links to a Life, http://www.linkstoalife.com/ who would be happy to work with those interested to develop similar days with the work of other historical figures in science) during the central part of the day. The rest of the day consists of facilitated workshops relating the curriculum scientific content, facilitated by teachers and /or science educators. Please note that the Lise Meitner Day was created and developed by Links to a Life, and the play and teaching materials are copywright to Vince Miles (play) and John Teasdale (workshop materials). This project has been subsequently adapted to form this Creations project masterclass/demonstrator; future activities along the same lines would need to develop new theatrical/drama responses to the lives of significant scientists with the appropriate links to the curriculum. The masterclass fosters links to current research and innovation in the form of engaging with CERN's schools programme via Skype.

The following text describes the specific Links to a Life event which has been placed at the centre of this particular version of a drama/science activity day (please note that this text is © Links to a Life and should not be reproduced in its current form)

'Bringing wider public attention to Lise Meitner's role in the discovery of 'nuclear fission', her humanity and her lasting impact on the modern world, Links to a Life, a creative learning company, has created a day-long programme for secondary schools including an hour-long piece of theatre at the centre with associated workshop games, hands on calculations and debate. The day is designed to inspire a passion like hers for Physics. Links to a Life sheds light on the dramatic and at times life threatening events of her life alongside an exploration into the Maths and Physics she grappled with in order to arrive at the theoretical explanation of the splitting of the uranium atom. The performance exposes audiences to her life, her associates (Boltzmann, Planck, Rutherford and Chadwick), the Maths behind her discovery and its historical context.'

The demonstrator's main aim is to link scientific theory and practice to the dramatized real life experiences of a scientist who made a significant contribution to the development and application of these theories. The opportunity to engage with the scientific and autobiographical content through drama– brings the theory to life by linking it to individuals and their social/historical context. The follow-up workshops engage creatively and dialogically with the scientific material in more detail, with connections to the dramatic presentation maintained by scientific facilitators during the follow-up workshops.

The project is aimed at students between 13 and 18 years old and takes a 'vertical learning' approach, by including students from different year groups who can support and challenge one another in terms of applying existing scientific knowledge. The project is facilitated by actors and teachers/scientists together, and can be developed in cooperation with researchers and/or scientists from a range of different settings, in collaboration with theatre companies and/or school drama departments.

4.2 Student needs addressed

Students will be supported in understanding abstract concepts such as standard form and radioactivity, by situating them within a dramatic context. This will help them to visualise the ideas, as well as the demonstrator activities giving an opportunity to practice their skills in linking the mathematics and science together. Through a CERN 'virtual visit' they are also guided to see the relevance of the scientific concepts to present day cutting edge science, thus offering a way to engage pupils despite the challenging content of the subject.

5. Learning Activities & Effective Learning Environments

Please note that this aspect of the demonstrator has been completed relating to a specific version, created by the creative learning company 'Links to a Life and adapted for the CREATIONs project masterclass. However, it could be adapted to relate the curriculum to the life work of any scientist brought to life through drama. Science topic: Nuclear Fission (Relevance to national curriculum) GCSE and A-level physics related to atomic structure, bonding and radioactivity Class information Year Group: Mixed Year 9-13 Age range: 13-18, but the inclusion of older participants is advised in order to facilitate the learning Sex: both Pupil Ability: The approach is designed to help pupils access and engage with an abstract topic in physics and maths, so although challenging it is designed to facilitate engagement of all pupils.	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) Creations project toolkit materials (e.g. wheels, honeycombs) ; a workbook relevant to the topic ; a drama. A space suitable for drama about science (e.g. a spacious laboratory) with a 'backstage' area is required and a classroom. Capacity to teleconference with a relevant research setting.
Prior pupil knowledge No prior knowledge is required about the historical figure central to the scientific concept. Otherwise, some prior knowledge might be helpful dependent on the central figure of the day. In this case, knowledge of a basic model of atomic structure is helpful.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will develop an understanding of nuclear fission and standard form in Mathematics. They will be able to link this learning to the development of scientific knowledge and understanding of the atom and sub-atomic particles over time.		
Assessment Pupils' workbooks; responses to questions	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* 'Vertical' groups to facilitate peer support for younger pupils or those who find accessing the concepts more challenging.	**Key Concepts and Terminology** **Science terminology:** Nuclear fission, radioactivity, sub-atomic particles, standard form **Arts terminology:** Exploring characterisation, illuminating human narratives, empathetic understanding, understanding drama techniques through 'close-up' encounters with the actor's craft, physical learning

Session Objectives: During this scenario, students will engage with a researcher studying science at the cutting edge relevant to the historical figure's work, as a preparatory Q&A session (e.g. CERN's Virtual Visits). During the masterclass, they will engage in activities to learn about nuclear fission and standard form developed by 'linkstoalife', supported by some of the 'creations' toolkit and features to develop engaging pedagogical approaches. The centrepoint of the day is a drama about the life of Lise Meitner, produced by a creative learning company 'linkstoalife'. Following the drama, the learning will be consolidated by a Plenary session in which pupils ask and answer questions about the key topic. This is a fun and active (and competitive) game which consolidates the learning before we move to the debate around issues raised from her story.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with	Students engage with questions relating to the Physics and Maths behind nuclear fission through question posing in taught sessions and interaction with the drama activity.	Provides initial questions and factual responses to consolidate/give new knowledge in order to further students' ability to apply	Investigation of the Physics/Maths content through links to the biographical and dramatic content.

	different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.		existing Physics/Maths knowledge	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students engage with the CERN data prior to the Masterclass via a Virtual Visit.	Facilitate virtual visit and follow-up activities including 'Happy families' card game to revisit factual content in a playful manner.	Students could create own happy families fact cards; possibilities of artistic representations of data encountered via CERN virtual visit.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students engage with a range of evidence relating to the discovery of nuclear fission, including source material from the scientists involved.	Provide resources in terms of physical data and factual knowledge to support dialogue and engagement with evidence.	Possibilities for students to create own drama activities in response to aspects of the scientific processes under exploration.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students apply mathematical knowledge to calculate energy released during fission reaction, working in mixed age groups and in dialogue with teachers.	Provide support for mathematical tasks and facilitate dialogue to enable constructive discussion and experimentation with knowledge.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students apply mathematical knowledge to calculate energy released during fission reaction, working in mixed age groups and in dialogue with teachers.	Provide support for mathematical tasks and facilitate dialogue to enable constructive discussion and experimentation with knowledge.	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students participate in a 'relay' game to respond to questions about Meitner, her life, the science and the moral dilemmas and possible future advantages/ disadvantages of the Nuclear technology resulting from Meitner's discovery including Nuclear power and atomic weapons. Students are given a question per group to discuss amongst themselves. Students present their views to the session as a whole.	Facilitate responses and moderate responses as necessary.	Possibility of discussing questions 'in role' as scientists
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students participate in a 'relay' game to respond to questions about Meitner, her life, the science and the moral dilemmas and possible future advantages/ disadvantages of the	Facilitate responses and moderate	Possibility of discussing questions 'in role' as scientists

		Nuclear technology resulting from Meitner's discovery including Nuclear power and atomic weapons. Students are given a question per group to discuss amongst themselves. Students present their views to the session as a whole.	responses as necessary.	

6. Additional Information

Lise Meitner:
The Battle For Ultimate Truth

FREE Vertical Year Group Physics/Drama Masterclass

Tuesday 13 March 2018
10.30 – 3, St Luke's Campus, University of Exeter
Led by Links to a Life with UoE staff

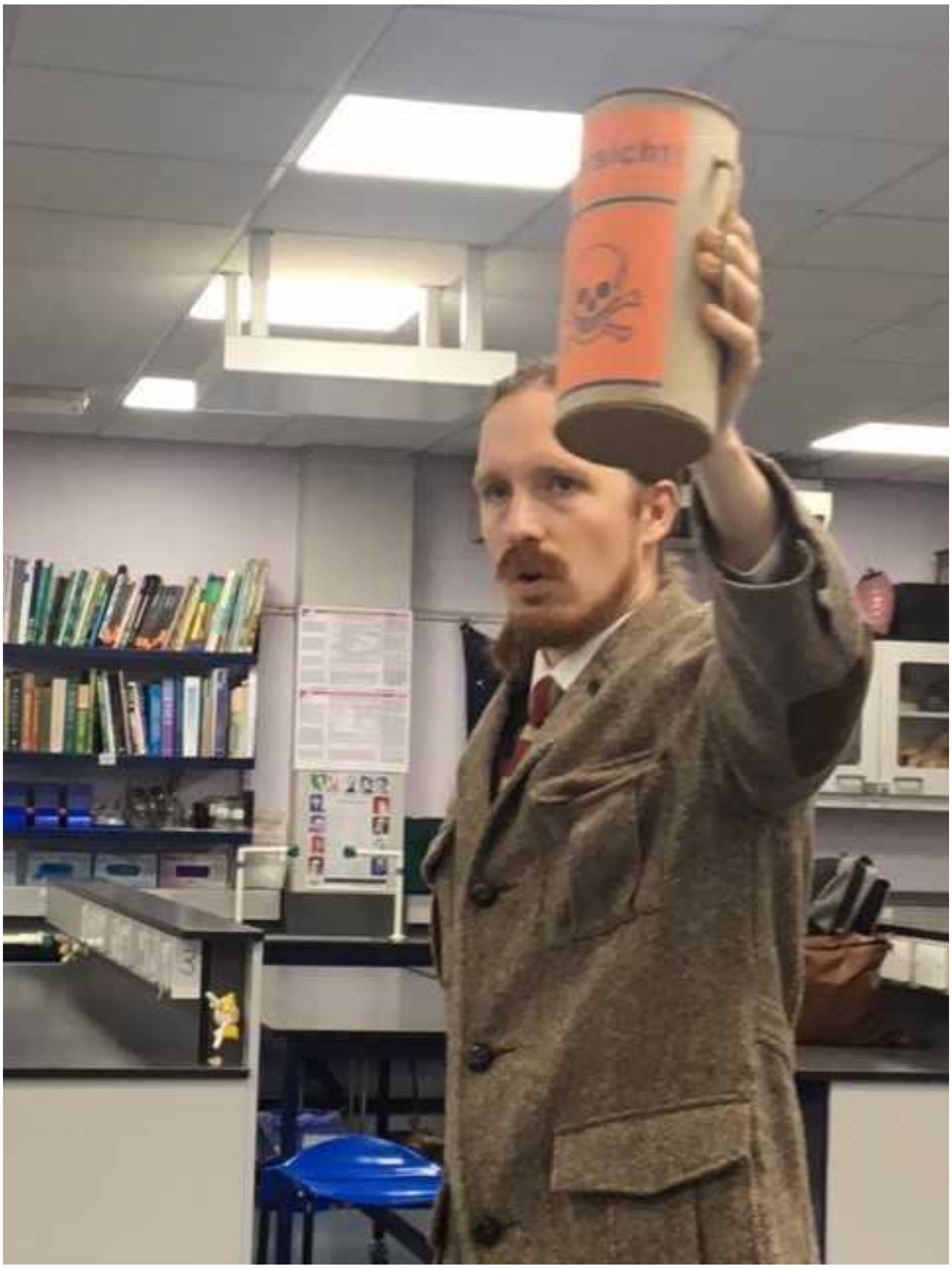
First come first served: please book places by emailing:
Hermione Ruck-Keene h.ruckkeene@exeter.ac.uk

The Masterclass puts the spotlight on one of science's unsung feminine heroes, the ground breaking Austrian atomic Physicist Lise Meitner. This Masterclass: 'Lise Meitner: The Battle for Ultimate Truth' dovetails into the national curriculum, and includes an immersive educational experience, culminating in a production of the play "The Lise Meitner Story" by Devon-based playwright Vince Miles in the St Lukes, UoE science lab. This is accompanied by participatory workshops exploring her life and the science within it.

We are looking for a maximum of 10 students per school from across all year groups, and at least half to be girls, please. We will also be running a short teachers' workshop on the day to which we are happy to welcome 2 – 3 staff members from each school. We are able to offer participating schools a free skype session to be arranged in school time, with colleagues at CERN to explore the Physics in more detail. Once you have secured a place at the Masterclass we will help you in arranging the Skype session. We also ask that participants assist us with project data collection before and after the event through questionnaires which will require parental permission.

This Masterclass is part of the CREATIONs project and is being run in partnership between the UoE CREATIONS team and Links to a Life (Producer: Rae Hoole) The EU-funded CREATIONs project aims to develop more engaging science classrooms by applying creative and arts-based approaches. At University of Exeter, it is being led by Dr Kerry Chappell from the Centre for Creativity, Sustainability and Educational Futures in the Graduate School of Education.

Images from the play, staged in the science labs:



7. Assessment

Pre- and post-test questionnaires will be administered to all students participating in the Masterclass; pre-test will be administered at least two weeks before the activity, and post-test at the end of the day. Teachers will complete the post-test questionnaire at the end of the day. Qualitative data will be collected in the form of observations, photographs and interviews with both students (group) and teachers (individual); teacher follow-up interviews will take place after the event to provide further insight into the impact of the activities.

8. Possible Extension

The activities outlined above could be used to develop similar activities related to other historical figures in Science, with a particular focus on mis- or under-represented individuals and/or groups. Links to a Life are happy to enter into discussion with European partners regarding development of similar drama/workshop masterclasses linked to significant figures throughout the history of Science. Similar techniques could also be used to engage with living or imagined scientific figures; for example, students could create dramatic representations of the types of scientists that they might envision themselves becoming, or scientific innovations that they would like to lead. This type of activity would also encourage students to consider the limitations or barriers that might be placed in their way – whether social, moral, economic or intellectual – and how they might overcome them, linking to the CREATIONS feature of ethics and trusteeship and developing the idea of resilience in a scientific context.

9. References

D.3.2.25. Action Research Project at Exeter University

Project Reference:	H2020-SEAC-2014-1 , 665917	Editing: C. Hathaway, K. Chappell, H. Ruck-Keene, K. Postlethwaite
Code:	D 3.2.25	
Version & Date:	**FINAL**	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science

The Arts

Teacher Development and accompanying student science engagement

Action Research (AR)

1.2 Type of Activity

University based for training.

School based to carry out investigation with pupils.

Involving the following:

Desired target 5 pairs of teachers from either Primary or Secondary schools across the UK. The pairs should involve a mix of science and arts teachers from the same school

1.3 Duration

1 year

Initial AR meeting: A training meeting at The University of Exeter in the Spring of 2017

Interim meeting: A skype/telephone/face to face meeting depending on geographical location of the school, accompanied by science/arts teaching and learning driven by the action research process

Second AR meeting: A training and sharing meeting at The University of Exeter in the Summer of 2017

Interim meeting: A skype/telephone/face to face depending on geographical location of the school, accompanied by science/arts teaching and learning driven by the action research process

Final meeting: A sharing and dissemination event at the University of Exeter in Spring 2018

1.4 Setting (formal / informal learning)

Venue: St Luke's Campus, Dance Studio, University of Exeter.

CREATIONS AR Programme Day 1 Programme March 1st 2017

9.30am: Arrival and refreshments

10 – 10.30am: Welcome and introduction to the project and all participants through creative ice breakers

10.30 – 11.15am: CREATIONS project features workshop

11.15 – 11.30am: ODS portal and surrounding evaluation and research

11.30 – 12.30pm: Rae Hoole from Lisa Meitner Science Arts project presenting/provoking discussion - briefly connect up Rae's last questions/provocations with AR questions of pairs

12.30 – 1.15pm: Lunch

1.15 – 2.15pm: Intro to Action Research. What is AR? What makes a good AR question? What kinds of data collection tools can we use? Who can we get to use them? What ethical considerations should we be thinking about? (brief intro) What are we doing between now and April? Our evaluation/impact/research questions?

2.15 – 3.15am: Mentors spend time with pairs working on honing question and getting basis of study manageable and discussing workable timeline and next point of contact

3.15 Wrap up/questions

The second two training days have a similar format although are responsive to the Action Research phase that the pairs are at.

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** The action research days include a mixture of formal presentations about the project, the available resources (portal) and ethics, workshop type activities exploring the CREATIONS features. There are whole group discussions facilitated by the leader, small group discussions between teachers and mentors, presentations of existing good practice / projects, and informal icebreaker type activities.
- **Arts-based:** the teacher pairs explore the CREATIONS features through collage making and exploratory movement activities as a stimulus to generate their own ideas for their investigation. They are exposed to a successful Science Arts project to provoke their thinking.
- **Dialogic space / argumentation:** Questions that shape the day include: What are the CREATIONS Features? What does interdisciplinary work between the arts and sciences look like? What is Action Research? What makes a good Action Research question? What kinds of data collection tools can we use? Who can we get to use them? What ethical considerations should we be thinking about? Through questioning and dialogue the teachers will be encouraged and allowed to express their ideas on how to shape their Action Reteach project.
- **Visits to research centres (virtual/physical):** The teachers will be registered on to the ODS portal as a tool to communicate virtually with other scientists, artists, teachers. They are also encouraged to visit the CREATIONS Website and Facebook pages and follow CREATIONS on Twitter.
- **Communication of scientific ideas to audience:** Teachers have access to experienced university science lecturers and the resources available to them on campus. They watch a presentation and have discussions around a completed successful arts and science project as an example of how you can communicate a scientific idea to various audiences.

2. Rational of the Activity / Educational Approach

2.1 Challenge

Advertising and recruiting onto the action research project, to overcome this information is sent out via various channels i.e. university partnership emails, advertise on the university website, social media platforms and teacher specific websites like the TES.

Minimal cover costs are made available to the teachers as a compensation for their time.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The workshop aims to extend teachers understanding of:

- how the arts and sciences can work together to develop children's learning and how these two approaches can inform and inspire each other
- how the arts can be used as a tool to open up dialogue about scientific ideas
- action research process as a tool for professional development and ongoing pupils' engagement in science
- cross departmental work in schools and the benefits of working with colleagues from different departments to build their own community of practice.

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3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the programme are:

- To carry out an AR investigation and develop interdisciplinary projects to develop more engaged science classroom learning
- To engage with an interdisciplinary process of the arts and sciences
- To plan and see through their own AR project
- To carry out a AR investigation in their setting
- To engage with a group of school children in an arts and science project
- To develop engaging science lessons that have the potential to inspire and appeal to children to consider a future career in the sciences

3.2 General skills objectives

The expected general skills to be acquired or improved through the various workshops are:

- To be able to work with their peers
- To understand the action research process
- To understand ethics in research
- To explore and play with arts activities as a stimulus for inquiry in science
- To generate questions, inspired by these activities
- To develop new pedagogical knowledge
- To Promote curiosity about interdisciplinary work
- To Engage in fun group activities and rich discussions
- To explore a kinaesthetic approach to the learning of the CREATIONS Features

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the demonstrator is to use action research and interdisciplinary projects to develop more engaged science classroom learning.

4.2 Student needs addressed

The list includes:

- Promote curiosity about interdisciplinary work
- Engage in fun group activities and rich discussions
- Develop deeper knowledge of science topics through inspiring activities
- Gain an appreciation for how the arts can develop / support / interact with the sciences
- To increase their wonder of the world around them
- Inspire pupils to consider a career in the sciences
- See potential benefit of learning in an interdisciplinary way

5. Learning Activities & Effective Learning Environments

<table>
<tr><td>Science topic: Any
(Relevance to national curriculum)
Class information
Year Group: Any
Age range: Any
Sex: All
Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) all inclusive</td><td colspan="2">Materials and Resources
What do you need? Resources will depend on the line of enquiry decided
Where will the learning take place? The space will depend on the line of enquiry decided
On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one? Will depend on the line of enquiry decided
Health and Safety implications? Will depend on the line of enquiry decided
Technology? Will depend on the line of enquiry decided
Teacher support? Will depend on the line of enquiry decided</td></tr>
<tr><td colspan="3">Prior pupil knowledge
Depending on the line of enquiry, you may decide to use the project to introduce concepts to pupils or build on their existing knowledge</td></tr>
<tr><td colspan="3">Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)
During this scenario, pupils will
• pupils will learn about the science-arts topics being researched
• pupils will develop their understanding of the chosen science-arts topic
• pupils will engage in a science-arts project
• pupils will see action research being used by teachers as a reflective means to develop their own understanding</td></tr>
<tr><td>Assessment</td><td>Differentiation</td><td>Key Concepts and Terminology</td></tr>
</table>

Questioning and dialogue throughout the day. Teachers will complete evaluations at the end of the day, pupils will conduct evaluations at appropriate points during the project.	*How can the activities be adapted to the needs of individual pupils?* **Planning of the activities will include differentiation tasks. The adult / tutor leading the task will be an expert so will differentiate when needed through questioning.**	*Science terminology:* **depending on the line of enquiry decided appropriate terminology should be introduced and utilised throughout the project** *Arts terminology:* **depending on the line of enquiry decided appropriate terminology should be introduced and utilised throughout the project**

Session Objectives: (Depending on where in the processes)

- Teachers will explore and play with arts activities as a stimulus for inquiry and promote curiosity about interdisciplinary work, they will generate questions, inspired by these activities and conduct an action research project in their own setting
- Pupils will participate and engage in an science-art project that will develop their understanding for the science topic explored

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONS Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation*	**The investigation will be driven by the pupil's questions to allow for agency and empowerment, their**	**To aid the pupils the teachers will need to scaffold the session depending on the project and what their**	**Pupils will be capturing photographs or videos of objects / issues / phenomena**

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	through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	**curiosity will drive their investigation.**	**individual pupil's needs are to ensure the balance between science knowledge is gained and the pupils are able to navigate the arts across their work they engage and create.**	**in their school setting that they wish to challenge / change / develop.**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and*	**To develop communal activity pupils will be encouraged to**	**Teachers will need to ensure that pupils have the tools to capture their evidence and know**	**Depending on the project pupils might document their evidence through**

	communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	**discuss and work together to collect evidence of their investigation.**	**what and how they will go about this, they might need support / training to use equipment.**	**video camera, iPad, photography, audio recording, reflective diaries, creative writing.**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	**With the learning environment scaffolded by the teacher the pupils will analyse their evidence, this could be conducted individually or in groups depending on the project.**	**Teachers will question pupils to ensure links between ideas are understood and provoke thinking deeper.**	**Using the evidence generated the pupils can analyse the photos or videos they have generated.**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of	**Pupils will engage in discussions throughout the project verbally, physically and creatively.**	**If the pupils lack knowledge of different art forms the teachers will need to ensure at the planning stage what might benefit the pupil's investigations and**	**To explain their results the pupils might create a collage of images or turn the videos into a short movie.**

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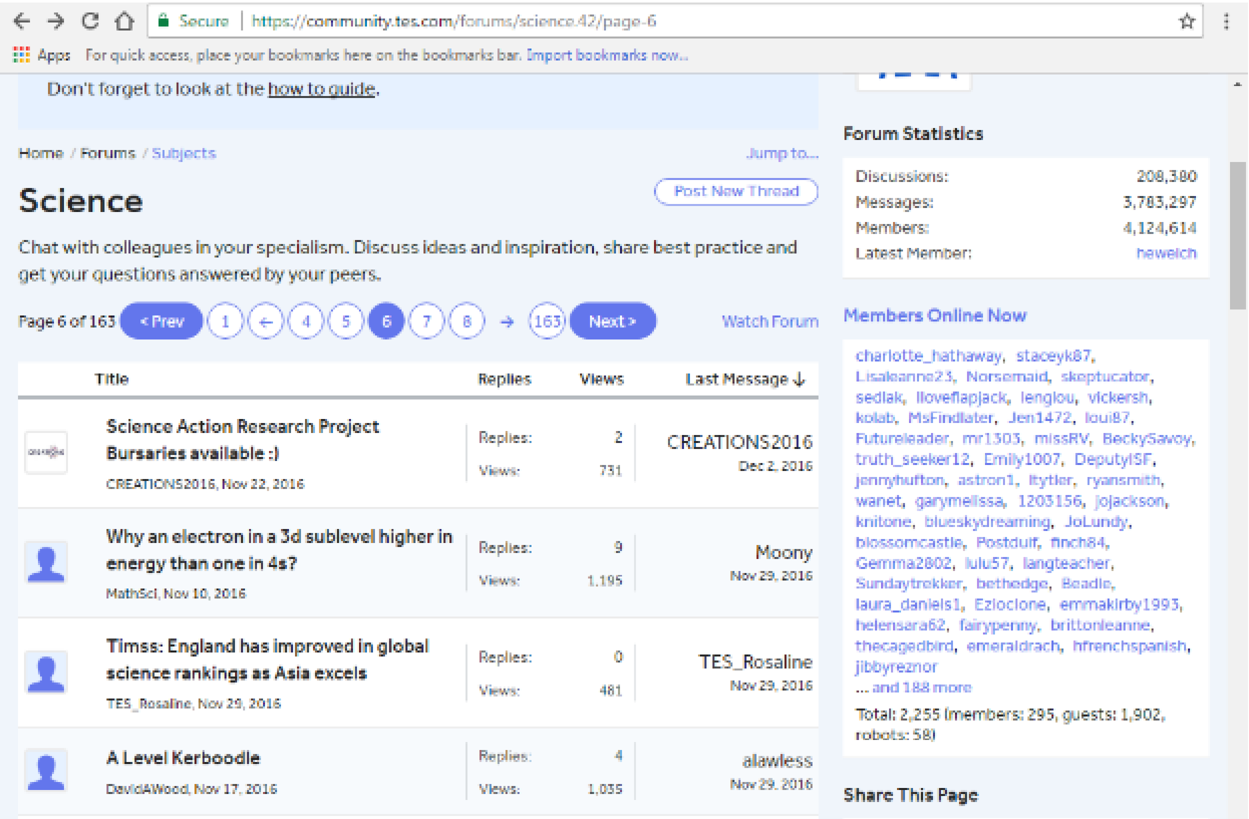
	the explanations they formulate, *playing* with ideas.		**introduce them to various techniques.**	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	**The teacher will need to challenge the pupils to make connections between their scientific knowledge and how to could present this in various artistic forms.**	**Teachers will question pupils to ensure links between ideas are understood and provoke thinking deeper.**	**Pupils can use the collage of images generated at the evidence stage as a stimulus for a piece of drama, movement or musical composition.**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer	**Depending on the project pupils might work individually, in whole groups and or small group.**	**For the pupils to successfully communicate their investigation teachers will need to ensure the plan enough time for the pupils to develop**	**Pupils will perform their dramatic scene, musical composition or movement piece to an audience to**

	students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.		**and explore their ideas, they will need to ensure pupils have access to appropriate resources and space to perform in.**	**engage in dialogue and feedback.**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	**Time will be dedicated at appropriate points in the project for the pupils to complete pre-and post-tests.**	**Teachers will ensure they carry out on going reflections throughout the project and will complete the teacher evaluation questionnaire at the end. The teachers will also register with the portal and encouraged to engage with post discussions across social media and the ODS Portal**	**Both Pupils and Teachers might decide to conduct a video reflective diary or create an art project to summaries their reflections. Teachers might decide to engage in Accordion book reflections.**

6. Additional Information


Secure | https://community.tes.com/forums/science.42/page-6

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Title	Replies	Views	Last Message
Science Action Research Project Bursaries available :) CREATIONS2016, Nov 22, 2016	Replies: 2	Views: 731	CREATIONS2016 Dec 2, 2016
Why an electron in a 3d sublevel higher in energy than one in 4s? MathSci, Nov 10, 2016	Replies: 9	Views: 1,195	Moony Nov 29, 2016
Timss: England has improved in global science rankings as Asia excels TES_Rosaline, Nov 29, 2016	Replies: 0	Views: 481	TES_Rosaline Nov 29, 2016
A Level Kerboodle DavidAWood, Nov 17, 2016	Replies: 4	Views: 1,035	alawless Nov 29, 2016

Forum Statistics

Discussions:	208,380
Messages:	3,783,297
Members:	4,124,614
Latest Member:	hewelch

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charlotte_hathaway, staceyk87, Lisaleanne23, Norsemaid, skeptucator, sedlak, lloveflapjack, lenglou, vickersh, kolab, MsFindlater, Jen1472, loui87, Futureleader, mr1303, missRV, BeckySavoy, truth_seeker12, Emily1007, DeputyISF, jennyhufton, astron1, ltytler, ryansmith, wanet, garymelissa, 1203156, jojackson, knitone, blueskydreaming, JoLundy, blossomcastle, Postduif, finch84, Gemma2802, lulu57, langteacher, Sundaytrekker, bethedge, Beadle, laura_daniels1, Ezloclone, emmakirby1993, helensara62, fairypenny, brittonleanne, thecagedbird, emeraldrach, hfrenchspanish, jibbyreznor ... and 188 more

Total: 2,255 (members: 295, guests: 1,902, robots: 58)

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7. Assessment

The Teacher feedback questionnaire is used at the end of the workshop.

The Pupil pre-and post-test will be conducted at the start and end of the project.

Depending on the project design additional Pupil questionnaires / reflections / interviews will conducted at as appropriate and at various points of the AR programme.

8. Possible Extension

Dependent on the quality of the outcomes of the Action Research some of them will have the capacity to be turned into Demonstrators in their own right.

9. References

D3.2.26 Masterclass at Exeter University

Project Reference:	H2020-SEAC-2014-1 , 665917	Editing: C. Hathaway, K. Chappell, H. Ruck-Keene, K. Postlethwaite
Code:	D 3.2.26	
Version & Date:	**FINAL**	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics

Light

Photography

1.2 Type of Activity

University based.

Involves the following:

University Tutors: 5 Tutors from the University of Exeter

Artist: Sam White

Scientist: Professor Pete Vukusic

School: Local secondary schools invited to attend; 4 attended

Number of Children: 40 children between the ages of 11 and 13

Number of Teachers: 7 Teachers were in attendance

1.3 Duration

One day (e.g. 10:30am – 3pm January 31st 2017)

1.4 Setting (formal / informal learning)

Streatham Campus, University of Exeter

Starting formal: introductory talk: a lecture demonstration by Professor Vukusic and a Camera Obscura Workshop with Sam White.

Continuing informal: workshop is split into three sections. Part A: Light boxes – pupils working in small groups on an activity, which encourages creative exploration of the behaviour of light, leading to the formulation of scientific questions about that behaviour. Part B: Four stations are set up with a university physics tutor or doctoral student leading one activity. The children rotate around the stations in a carousel, spending 5 minutes on each station.

Finishing formal: Part C: plenary and reflection

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** The Masterclass includes seminars and hands-on activities working with physics and photography to bring light and colour to life. The pupils are encouraged to work together in small groups with some physicists and physics educators from the university. Then during part B and part C, the pupils have opportunities to generate and ask questions about the processes they explored.
- **Arts-based:** Artist Sam White introduces the fundamentals of light through his Camera Obscura with the pupils. The pupils also explore art activities as a stimulus for scientific investigation e.g. using the art of Bridget Riley and Pery Burge as inspiration, pupils then explore Interference, Structural Colour, Refraction and Colour Mixing through activities involving paint, bubbles, light boxes, water.
- **Dialogic space / argumentation:** Questions shaping and driving the day included: how light behaves, how we can play with colour, and why this is important to interacting with that and understanding the world around us. The Masterclass provides an opportunity to link concepts about reflection and refraction of light in the KS3 curriculum and explore them in new and exciting contexts. Through questioning and dialogue the pupils are encouraged and allowed to express their ideas on how light can be manipulated, explored and played with.
- **Visits to research centres (virtual/physical):** The Master class was conducted at The University of Exeter, Devon, UK. http://www.exeter.ac.uk/visit/campuses/streatham/
- **Communication of scientific ideas to audience:** Professor Vukusic's work in Biophotonics explores the manipulation of light by biological systems and began with iridescence in butterflies. His workshop allows the pupils to explore various physics concepts around light using equipment that is common in schools and equipment that is usually first encountered at university.

2. Rational of the Activity / Educational Approach

2.1 Challenge

The Master class is inspired, in part, by the concept of "conversive trauma" (Hargreaves, 1983) which suggests that the affective reaction to a work of art can be the stimulus to find out about the processes involved in its creation, rather than understanding of those processes being the basis on which the affective response is based. This is consistent with Woolnough and Alsop's (1985) notion that one purpose of science practical work in schools is to give pupils a 'feel for the phenomena'. (Pushing a balloon into water is great way of getting a feel for the phenomenon of upthrust.) Once this "feel" is established, detailed exploration of the phenomenon can be undertaken with meaning (and enthusiasm).

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

Master class aim: To extend pupils' understanding of:

- how science can understand the behaviour of light
- how artists can explore the manipulation of light
- how these two approaches can inform and inspire each other

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the Master class:

- To understand that light travels in straight lines
- To understand reflection and refraction – two mechanisms that change the direction of light rays
- To understand interference – what happens when coherent light waves interact
- To explore structural colour – colour which is perceived as a result of interference
- To explore and play with colour mixing
- To explore their own curiosity about light
- To generate questions, inspired by these activities, about the world around them

3.2 General skills objectives

The expected general skills to be acquired or improved by the Masterclass:

- To understand how we can manipulate light beams
- To be able to understand how simple optical instruments work by looking at ray diagrams
- To make and explore the camera obscura
- To make a pinhole camera
- To understand how scientists work within a multi-disciplinary group where each member is an expert on their field
- To be able to work with their peers
- To leave having created some questions

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of this demonstrator is to use a creative way to introduce the concepts of physics and light.

4.2 Student needs addressed

The list includes:

- Promote curiosity about light
- Engaging in fun group activity that has a clear educational purpose
- Kinaesthetic approach to the learning of the concepts of light reflection, refraction and interference, colour mixing
- Understanding of how science works

5. Learning Activities & Effective Learning Environments

Science topic: **Light** (Relevance to national curriculum) Class information Year Group: **7 / 8** Age range: **11-13** Sex: **both** Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) **all inclusive**	Materials and Resources *What do you need?* **Large space to facilitate the students moving around the stations** **Interactive white board** *Where will the learning take place?* **University campus** *On site or off site?* **On site** *In several spaces? (e.g. science laboratory, drama space etc), or one?* **In a room that can facilitate lecture and group work** *Health and Safety implications?* **School will have a risk assessment, see university risk assessment for visitors** *Technology?* **Interactive white board** *Teacher support?* **Yes. To encourage and help as necessary**
Prior pupil knowledge **N/A**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* **During this scenario, pupils will** • **Listen to the introductory talk and answer questions about light** • **Take part in Camera Obscura workshop** • **Engage in different stations exploring light** • **Construct a pin hole camera**	

- **Generate their own questions**

Assessment	Differentiation	Key Concepts and Terminology
Questioning and dialog throughout the day. Some pupils and Teachers will be invited to be interviewed after the event	*How can the activities be adapted to the needs of individual pupils?* **Planning of the activities will include differentiation tasks. The adult / tutor leading the task will be an expert so will differentiate when needed through questioning.**	**Science terminology:** **Reflection, refraction, interference, colour mixing,** **Arts terminology: Photography, light, image, representation, camera obscura, artistic choices**

Session Objectives:

- **Listen to the introductory talk and answer questions about light**
- **Take part in Camera Obscura workshop**

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- **Engage in different stations exploring light**
- **Construct a pinhole camera**
- **Generate their own questions**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of	**Pupils engage with teacher's questions, watch power point presentation, listen to talk by scientist and artist (interdisciplinary) and demos and try to interpret their own through about light. Adults will trust the pupils as they explore the concepts.**	**Supports the pupils through out the day by questioning the pupils to develop their thinking**	**Graffiti wall to captures pupil's thoughts as they work through the workshop. Pupils can visit the wall and write any questions, thoughts, comments they have.**

	professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is	**Pupils participate in different stations exploring light. They gain an insight into how we can explore in groups and play with light. They will be allowed to engage with the activities empowering them to**	**Adults will question pupils to ensure links between observations and conclusions are understood.**	**Pupils can capture aesthetically pleasing outcomes and create a record of what is going on by taking photographs or keeping a reflective diary**

	crucial in *empowering* pupils to generate, question and discuss evidence.	**take a risk and try various activities.**		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	**Pupils will analyse light during Part B**	**Adults will question pupils to ensure links between observations and conclusions are understood.**	**Create mind maps to record their developing understanding and the questions that this generates**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with	**Pupils will be asked to explain**	**Adults will question pupils to ensure links between observations and conclusions are understood.**	

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	ideas.			
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	**Part C: Discussion and question generating activities.**	**Adults will question pupils to ensure links between observations and conclusions are understood.**	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	**Pupils to work in groups and construct a camera a pinhole camera.**	**Adults will question pupils to ensure links between observations and conclusions are understood.**	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended	**Pupils to work in groups and construct a camera a pinhole camera.**	**Adults will help pupils as and if needed.**	**Exploring examples of cameras – artists' use of pinhole cameras e.g. http://www.nancybreslin.com/**

	inquiry learning and the curriculum and assessment requirements of education.			

6. Additional Information

Poster created to advertise the event for schools

CREATIONS UNIVERSITY OF EXETER Science & Technology Facilities Council

EXPLORING LIGHT & COLOUR: THROUGH PHYSICS & PHOTOGRAPHY

FREE Year 7 & 8 Physics Masterclass

Tuesday 31 January 2017
10.30 – 3, Streatham Campus, University of Exeter
Led by Professor Pete Vukusic and Sam White
First come first served: please book places by emailing:

The Masterclass will include seminars and hands-on activities working with physics and photography to bring light and colour to life. Professor Vukusic's work in Biophotonics explores the manipulation of light by biological systems and began with iridescence in butterflies; this will be investigated alongside photographer and artist's Sam White's practice exploring the fundamentals of light through his Camera Obscura. Bring your questions and curiosity about how light works, how we can play with colour and why they are important to interacting with and understanding the world around us. The Masterclass will link to concepts about reflection and refraction of light in the KS3 curriculum and explore them in new and exciting contexts.

This Masterclass is part of the CREATIONs project and is being run in association with the Science and Technology Facilities Council's Physics Masterclass Programme. The EU-funded CREATIONs project aims to develop more engaging science classrooms by applying creative and arts-based approaches. At University of Exeter, it is being led by Dr Kerry Chappell from

Event Schedule

CREATIONS Master class

Tuesday 31st January 2017
St Luke's Campus
University of Exeter
10.30am – 3:00pm

10:30am - 11:25am

Kerry brief intro to day
Pete's session 1 with Group A
(20 students + 2 teachers)

Alice brief intro to day
Sam session 1 with Group B
(20 students + 2 teachers)

11:35am – 12:30pm

Pete's session 2 with Group B
(20 students + 2 teachers)

Sam session 2 with Group A
(20 students + 2 teachers)

12:30pm – 1:30pm

Lunch (students to bring own, we provide sandwich lunch/hot drinks for staff)

1:30pm – 2:45pm (supported by Alice and PhD students)

Group A facilitated by Keith
1 Pinhole camera activity run by Sam (30mins)
2 Lightbox activity run by Keith (15 mins)
3 Lens activity run by Keith (15 mins)
4 Wrap up by Keith

Group B facilitated by Jill
1 Lightbox activity (15 mins)
2 Lens activity run by Jill (15 mins)
3 Pinhole activity run by Sam (30 mins)
4 Wrap up by Jill

2:45pm – 3:00pm Evaluation

Group A facilitated by Hermione

Group B facilitated by Kerry

(Ensure link to evaluation forms is available)

Funded with the Horizon 2020 Framework of the European Commission

CREATIONS Developing an Engaging Science Classroom

7. Assessment

40 Pupil feedback questionnaire completed at the end of the workshop.

7 Teacher feedback questionnaire completed at the end of the workshop.

1:1 interviews conducted with 10 Pupils and 1 Teacher

Video with examples of the pupils and teachers engaging with the Masterclass can be found here: https://www.youtube.com/watch?v=SmGrltwKLJE&index=1&list=PLe8vyktlR0b3CDrmqKQkHRmXS47pJ-V-t

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

There is a follow up project planned, using the same format of the Masterclass described, but with different partners in Spring 2018.

9. References

Hargreaves, D. (1983) The teaching of art and the art of teaching: towards an alternative view of aesthetic learning, in: M. Hammersley & A. Hargreaves (Eds) Curriculum Practice: Some Sociological Case Studies (London, Falmer)

Woolnough, B. and Alsop, T. (1985) Practical work in Science. Cambridge: Cambridge University Press

D3.2.27. Understanding Big Ideas in Science and Art (UBISA)

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Dr Paul Davies** **Hermione Ruck Keene**
Code:	D 3.2.27	**Contributors:** **Dr Lindsay Hetherington** **Dr Kerry Chappell** **Heather Wren**
Version & Date:		**Approved by:NKUA**

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Science (Biology, Chemistry, Physics, Earth Science)/Visual Art

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).

1.3 Duration

Two terms

1.4 Setting (formal / informal learning)

Informal learning: extra-curricular activity

1.5 Effective Learning Environment

- *Communities of practice*
- *Arts-based*
- *Dialogic Space / argumentation*
- *Communication of scientific ideas to audience*

2 Rational of the Activity / Educational Approach

The activity involved students working with Science and Art Teachers in both laboratory and Art Studio settings. The main approach was one of inquiry, with students developing their own questions about 'big ideas' in science and solutions to these questions – through the form of creative arts.

2.1 Challenge

Science and Art are often seen at two, disparate subjects. Students typically see the epistemology of Science as being fact-laden developed from postivistic approaches. Art, on the other hand is often perceived as subjective and developed through imagination and creativity, avoid 'rule-based' approaches to knowledge construction.

In reality, there is considerable overlap in the way that science and art is constructed (although this is not often seen in school). There is a challenge to help students udnerstand the realities of how knowldge is created.

Beyond this, the big ideas of science are abstract and present a challenge for students to comprehend. Developing a shared language is a key aspect to students building up their own explanations. In the project, it is the creation of art that allowed for this to take place.

2.2 Added Value

The project is deisgned to help students udnerstand the different ways that knowledge is constructed and used. It is also deisgned to encourage collaboration between teachers from different disciplines and to encourgae students to see that there are similarities in approaches to knowldge construction across the school curriculum. These skills and forms of knowldge are important aspects of developing intellectual citizens.

The project also supports a deepening understanding of big ideas in science. These underpin much of science and so, developing thought in this area, helps students to build confidence in their knowledge and make links within and across their learning.

3 Learning Objectives

3.1 Domain specific objectives

The UBISA domain specific objectives are to:

- *Introduce students to big ideas in science*
- *Teach student about the ways that Science and Art construct knowledge*
- *Get students to reflect on their own ideas about Science and Art*
- *Provide students with opportunities to make their own artwork*
- *Get students to explain their own understanding of the big ideas through their artwork*
- *Allow parents to understand the work that students produce*

3.2 General skills objectives

In the context of the UBISA, students' general skills objectives are:

- *Active participation in the negotiation of scientific concepts*
- *Allow students to experience learning in a cross-disciplinary way*
- *Develop creative and critical skills*
- *Understanding of scientific concepts and phenomena*
- *Scientific interconnection of science with aspects of art*
- *Develop spirit of cooperation and teamwork*
- *Develop skills in critical reflection and dialogue*

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4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim to give high school students the opportunity to explore big ideas in science through the construction of a piece of art work. During this process, students experience learning about science in a creative way – something which mimics the way that new scientific knowledge is constructed. They also develop an understanding about the relationships, and overlap, between ways of working and knowing in Science and Art.

The project is best run as an extracurricular experience and is focused on 12-14 year old students and involves collaborative work between at least one Science and one Art teacher. The Science teacher introduces a selection of 'big ideas' to the students (evolution, deep time, energy etc) by giving a brief overview of what they ideas involve and their importance in underpinning major ideas in science. After a period of reflection, the Art teacher then shows, and discusses a series of images of art creations that are inspired by science. These stimulus material are used to encourage students to reflect on how science ideas, being abstract in nature, have to be reimagined in creative ways.

The remained of the project involves students researching, designing and making a piece of creative art which explores a scientific idea. This process is best done in groups, where students can share developing ideas and critique their work. A project scrapbook is a useful way for students to record their developing ideas and collect images and other materials to support their thinking.

Central to the project is students' cognitive gain – both of scientific ideas and creation of art. Social interaction (between students and between students and teachers) is also central and it is useful for students to record how this supports their thinking. During the creative phase, student draw on their own personal histories as well as consider the sociocultural aspects of the construction of scientific knowledge. For example, if Forces and Energy was the scientific idea being explored, students would need to consider how Newtonian physics gave way to Einsteinian ways of thinking, not just as a development of ideas but also in terms of how societal changes supported a shift in thinking.

The project ends with a celebratory exhibition (including an exhibition catalogue recording the students' journeys) where students and parents explore the project. This works best if the teacher and students involved give an oral overview of the project and their reflections, and then facilitate discussion around the pieces.

4.2 Student needs addressed

The nature of the project is such that students can access it at different levels. The open appproach that allows students to explore a big idea in science their choice means they are free to develop their own ideas and understanding and take this as far as they wish. For example, a very able

student may explore particlate physics which a less able student may explore adaptation of animals.

Support by the teacher is vital to ensure the students can succeed. This is especial important when the students are thinking about the scientific ideas and how artists have been imspired by science.

Outcomes by the student are differentiated – this depend upon their cognition, creativity and skill. A strength of the project is that allows students the freedom to develop their own work in their own way.

5 Learning Activities & Effective Learning Environments

Science topic: Big ideas across the science. Covers themes like energy, forces, geological time, space, evolution, particles. (Relevance to national curriculum) Class information Year Group: 7-9 Age range: 11-14 years Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate) The open ended nature of the projects makes it suitable for all ability ranges	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) Images of artists' interpretation of big ideas in science Scrapbooks Art materials Cameras/mobile devices *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* Works well in both the Science and Art classroom *Teacher support?*
Prior pupil knowledge None needed although they will have met the various big idea themes in science lessons.	
Individual session project objectives *(What do you want pupils to know and understand by the end of the project?)* • *Introduce students to big ideas in science* • *Teach student about the ways that Science and Art construct knowledge* • *Get students to reflect on their own ideas about Science and Art* • *Provide students with opportunities to make their own artwork* • *Get students to explain their own understanding of the big ideas through their artwork* • *Allow parents to understand the work that students produce*	

Assessment	**Differentiation**	**Key Concepts and Terminology**
As the project is extra curricular, assessment can be light-touch. This can involve observations, reflection by the students and analysis of their scrapbooks and exhibition writing.	Outcomes by the student are differentiated – this depend upon their cognition, creativity and skill. A strength of the project is that allows students the freedom to develop their own work in their own way.	Science Art as domains of knowledge 'Big ideas' in Science Creativity **Science terminology:** Forces, Energy, Deep time, Evolution, Particles **Arts terminology:** **Creativity, Realism, Surrealism, Modernist, Iconography**

Session Objectives:

During this scenario, students will explore 'big ideas' in science through visual media.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students are shown some images that express ideas about 'big ideas' in science. There are then asked to discuss each image in terms of what it means, what it might mean and what different people might think about the image. The students then look at images of (or real) artwork that is inspired by science. Again, they explore the meaning in these images/pieces. The discussion is then shifted to why Science and Art are sometimes viewed as different types of knowledge. Students discuss overlap and synergy (e.g. creative thinking, abstract thinking; imagination; symbolism and symbolic representation). This then leads to them recording reflections in their scrapbook and starting to think about how they will creative a piece of art focused on a specific big idea. Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an	Watch images or science 'big ideas' and art that responds to science. Discuss the meaning of these images and relationships between science and art knowledge. Begin to consider own perspectives and creations.	Encourages discussion of the key themes with images and probe questions (include Devil's Advocate – 'What if……' etc.),	Looking at science inspired art work (could be in a gallery setting and producing artistic/creative responses. Exploring artists and their inspiration. Writing and producing creative responses.

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	important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students now explore and research their big idea and artists' responses to science, in more depth and discuss their emerging thinking with one another and teachers. They should also hear the teachers talking through their own thinking too. The research stage can involve books and internet resources, as well as knowledge that each member of the project has – this should be highly valued. Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Student research the big ideas artists and record their thinking in their scrapbook. Sharing of these ideas allows time for reflection.	Teachers should model thinking through problems and how a Science teacher and Art teacher might approach the same problem.	Exploration of artists and producing creative responses.
Phase 3: **ANALYSE:** students analyse evidence	Here students firm up their ideas with reflective dialogue amongst themselves and with the teachers. They will start to experiment with creative materials and discuss possibilities. Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Discussing their ideas and experimenting with materials and making.	Prompting deeper reflection ('Why?', 'What?' and 'How?' type questions). Possibility modeling methods of using creative materials.	Learning new artistic techniques e.g. brush techniques.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students make their creative piece in response to their big idea. This is a long process and iterative in nature. Discussion within the project group help to drive ideas and their should form reflections in the scrapbook. AS the pieces take shape, the students modified and change in light of their own developing thinking and comments from others. Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Making their creative pieces and discussing its design.	Prompting reflection and criticality in thinking with probe questions.	Making the creative piece
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	As the creative pieces are completed, students produce a piece of writing to accompany it. The writing explains their learning journey (including how their thinking about science and art knowledge has developed) and how the piece developed. It does not have to be an detailed explanation of the science, but should explain how the science inspired the piece and what a viewer of the piece might contemplate.	Writing an account of the development of their thinking and the development of the piece.	Provide prompts and frameworks to support the writing.	

	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			
Phase 6: **COMMUNICATE:** students communicate and justify explanation	The project ends with an exhibition where the students talk about their piece to an audience before people explore the pieces (here the students can stand by their piece and answer questions). The exhibition catalogue accompanies this experience and supports the students. Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Present their ideas and talk about their creative piece.	Introduce the exhibition with and overview of the project and reflections of their own.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	Here the students reflect on the entire project and write this in their scrapbooks. This should include ideas that emerged from the exhibition. They should focus on their views about form of knowledge and the relationship between science and art. They can also consider the silos of subjects in school and consider how	Writing their reflections.	Prompting and providing	

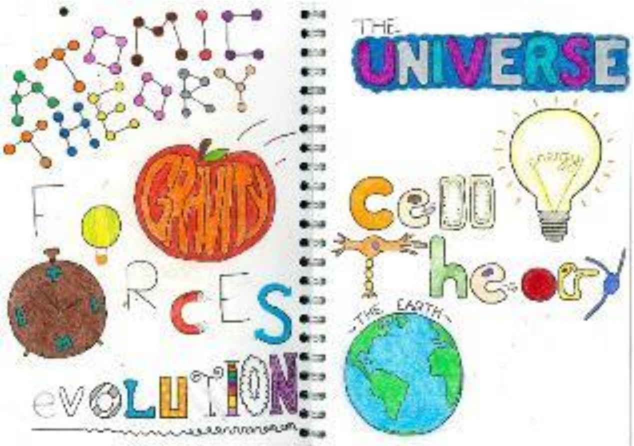
	a curriculum might be altered to support greater cross curricular collaboration. *Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.		sentences stems if necessary.	

6 Additional Information

Developing work:

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Scrapbook material



7 Assessment

As the project is extra curricular, assessment can be light-touch.

This can involve observations, reflection by the students and analysis of their scrapbooks and exhibition writing.

CREATIONS pre and post test student questionnaires.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8 Possible Extension

A good way to expand this project is through collaboration with either scientists and/or artists. For example, the Institute of Making, UCL, bring together experts from different disciplines to creative new artefacts. Taking the students to such a place gives them first-hand experience of the project in an applied setting.

9 References

Colucci-Gray, L., Burnard, P., Cooke, C., Davies, R., Gray, D., Trowsdale, J. (2017) Reviewing the Potential and Challenges of Developing STEAM Education through Creative Pedagogies for 21st Century Learning. *A Report from one of the BERA Research Commissions*. London, BERA.

D3.2.28 Student Parliaments

Project Reference:	H2020-SEAC-2014-1, 665917	**Authors:**	Menelaos Sotiriou (NKUA)
Code:	D 3.2.28	**Contributors:**	Zacharoula Smyrnaiou, Evagelia Petropoulou, Vasiliki Grigoriou (NKUA)
Version & Date:	**V1, 9/5/2016**	**Approved by:NKUA**	

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Biology, Engineering, Technology (The Future of the Human Being)

1.2 Type of Activity

The specific activity is a combination of:

(a) School based and

(b) school – research centre collaboration

As it is developed the activity can be characterised as a Large scale Activity at a National level

1.3 Duration

Approximately 5 months

1.4 Setting (formal / informal learning)

Both formal and informal. The setting involves classroom discussion and activities and visits to research centers and contact with relevant scientists both in presence and online.

Formal and Informal learning settings

- Classroom
- Venue for final debate event
- Research center (physical visit or virtual)
- Open Discovery Space portal (http://www.opendiscoveryspace.eu/community/greek-student-parliament-science-834221 - as a collaboration area)
- Activity's Website (http://studentparliament.weebly.com/ - for information, instructions etc.)
- The Adobe Connect platform for the communication of participants as well as the implementation of the final event (http://connect.ea.gr/studentparliament/). It allows connection with remote and/or rural schools.

1.5 Effective Learning Environment

- Communities of practice (web-based/physical)
- Dialogic space / argumentation
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2 Rational of the Activity / Educational Approach

2.1 Challenge

Although argumentation consists a core feature that accommodates the epistemology of science, science education has failed to incorporate it in its didactics (Smyrnaiou, et al., 2015). The same way argument and critique are essential skills in the scientific community for the delivery of its main objectives –production of new knowledge and reinforcement and validation of ideas (Osborne, 2010) – argumentation as an educational technique in science classes has been found to be tightly related to students' acquisition of scientific knowledge and enhancement in acquiring higher order skills related to problem-solving, scientific reasoning, communication capabilities and analytical thinking (Sandoval, 2003; Schwarz, et al., 2003).

By excluding the element of argumentation –as a "dialectical approach" -from the learning process of the science classes, we fail to instill in students the challenging aspect of scientific inquiry (Kuhn, 2005) and to enable them to develop a holistic view of the required process for the production of scientific knowledge and scientific discourse. Students deprived of this scientific procedure, either verbally by the lack of argumentation language or practically by the absence of inquiry practices, perceive science as a ready to consume product and an authoritative and sterile field that allows for no challenging exploration. The reason of deprivation of science education from argumentation and debate educational practices lies in the one-dimensional delivery of science instruction, strongly focusing on the transmission of knowledge rather than on the individual engagement in the process of understanding and perceiving the way we came to acquire this knowledge; a fact that is also emphasized by the curricula and the authorized educational material that support science teaching (Smyrnaiou, et al., 2015).

As a result, students fail to face and clear up the misconceptions they have on scientific issues and concepts since ready-made and indisputable explanations offered by their teachers leave no room for scientific reasoning and construction of scientific knowledge based on the ground premises of mental exploration, testing hypotheses, data collection and consequent discursive exploration. It is through the students' effort to make their claims comprehensible and sound while addressing others that engages them in deep rationalization and construction of solid knowledge (Jiménez-Aleixandre & Pereiro Muñoz, 2005; Sandoval & Reiser, 2004). However, learning derives as the product of the cognitive interaction and conflict between intuitive learning and new cognitive schemas and ideas that are structured by challenging our intuitions while engaged in situations in which we must provide data and arguments in order to support and strengthen our claims (Smyrnaiou, & Evripidou, 2012). Students engaged in argumentative interactions will be required to step back from their claims, examine their proposals with respect to counter-arguments, reflect on their current domain knowledge or submerging experimentation evidence and come up with new ideas that will be inner-examined in terms of scientific accuracy and validity (Erduran, 2014; Jiménez-Aleixandre & Pereiro Muñoz, 2005). Debates and collaborative discourse are valuable learning situations that enable students to undergo such a mental inquiry process where misconceptions can be tested and eliminated and suggestions and/or counter arguments by others facilitate the up-springing of new ideas, trigger more advanced claims and enhance individual engagement in the connection of claims with data (Jiménez-Aleixandre & Pereiro Muñoz, 2005; Sandoval & Reiser, 2004).

2.2 Added Value

The Student Parliament demonstrator is grounded on the Collaborative learning and Inquiry –based scientific approach in the form of argumentative discourse produced in collaborative problem-solving situations as an empowering interactive learning mechanism in which students engage cognitively in potential conceptual transformations and 'constructive interactions' (Smyrnaiou, et al., 2015). Students are engaged in a joint attempt of mutual understanding through argumentation interactions (Smyrnaiou, & Evripidou, 2012) which act as filters of intuitions and misconceptions (Osborne, 2010). Students participating in these communicative interactions become committed and are driven by the main objective to appear reasonable –in alignment to background/reference knowledge on scientific domain and application of relative discourse and subsequent norms. By having students work in collectives to prepare for a debate process against other teams, engaged in a search of providing strong and rational-based claims, the scope of the communicative interactions becomes wider, involving persuasion, convincing, problem-solving and engagement in an in-depth knowledge co-construction process (Jiménez-Aleixandre & Pereiro Muñoz, 2005).

In addition, students are given the opportunity to experience the challenging aspect of scientific inquiry and become engaged in the negotiation of authentic scientific issues/problems by providing and sharing multiple alternative perspectives for their solution. This way creativity and alternative thinking is instilled in students who are enhanced to come up with their own solutions to contemporary problems and challenges that need to be solved. Furthermore, the student-scientist exchange approach (directly communicate with scientists as well as visits to research centers) provides a challenging learning setting, rich in authentic information on current issues in science and research. Besides the context of the learning environment, a key aspect for the full realization of the Student Parliament demonstrator is the content of the activity that is defined by considering students' personal needs and interests in order to enhance students' mental engagement in the learning process. The future of the human being as a generic topic is challenging and relevant to students lives and allows plenty of room for differentiated exploration and approach guided by students own needs and interests. The specific topic involves issues on exploiting scientific and technological findings towards shaping a bright and sustainable future for the generations to come; issues more relevant nowadays than ever before and directly affecting youngsters' lives. In addition, this generic topic that invites for inquiry on the issue of the future of humanity has been subject of speculations and science through all times and most of all through different disciplines. Therefore, students will have to inquire and debate on a multidisciplinary and multi-dimensional issue applying their problem solving, critical and analytical skills and reflect and provide arguments for relevant bioethical issued that will arise.

3 Learning Objectives

3.1 Domain specific objectives

The main aim of the SP approach is to **improve pupils' enjoyment of and attainment in science via open-ended investigations**. Also, to give students opportunities to explore possible answers to scientific questions which are related to real life via practical and inquiry-based experimentation. This is achieved through providing opportunities for students to discuss key scientific concepts and processes with experts in the field. The

The SP's domain specific objectives are to:

- Get students interested in science and research through the parliamentary procedure
- Teach students how to form a qualified judgement and assess complex topics
- Initiate an objective discussion, particularly about controversial topics
- Initiate contact between students and scientists (particularly young scientists)
- Inform students about topics on a European or International scale
- Inform scientists about the views and new ideas of young people
- Build National-wide student networks

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop abilities necessary to do scientific inquiry
- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- design and conduct scientific investigations
- use technology to improve Investigations and communications
- formulate and revise scientific explanations and models using logic and evidence
- recognize and analyze alternative explanations and models
- communicate and defend a scientific argument
- develop lifelong learning skills
- develop attitudes befitting a scientific ethos
- link with science and society in a personal context

3.2 General skills objectives

In the context of the SP, students' general skills objectives are:

- Active participation and engagement in the negotiation of scientific concepts
- Developing creative and critical skills
- Understanding and applying the scientific inquiry approach (inquiring and developing arguments based on evidence)
- Connecting science with aspects of their everyday life
- Interacting with experts and experiencing at first hand scientific approach/attitude (demonstrating effective community building between researchers, teachers and students)

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- Developing spirit of cooperation and teamwork
- Acquiring lifelong learning skills

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is "to strengthen the dialogue and exchange of ideas between students and scientists, introduce students to parliamentary procedures on science and research, enabling students to form a qualified opinion and to assess complex topics, and introduce students to a scientific community" by inquiring and processing information on current issues in science and research.

The SP's main topic for negotiations is 'The future of the human being' further categorized in five sub-topics:

1) The Human Brain,
2) Living and eating healthy – but how?,
3) Stem cells – the potential allrounders?,
4) Augmented human: optimising the human and
5) Imitating nature.

In the activity participated 50 school teams from both public and private schools. The project is addressed at students between 16 and 19 years old in levels 10 to 12 with interest in the functioning of democratic systems, with interest in science and in learning about new topics, with ambitions to share their ideas in discussion. By immersing learners in active investigations of contemporary issues, and engaging them in collaborative discourse, they manage to constructively build on each other's ideas and enhance their learning of scientific concepts.

This Initiative is designed as an approximately 5-month project. School groups will be expected to spend at least 2 hours per week to explore and inquire the scientific issues under negotiation, communicate their ideas with scientific experts and prepare a set of arguments for the final debate event. However, inquiry and communication of scientific ideas or queries is also held through the communication forum of Open Discovery Space and also as a main tool for live communication is the Adobe Connect platform where a specific meeting place developed.

Students are free to present evidence or realization of their claims through creative, alternative and innovative approaches.

4.2 Student needs addressed

In the SP the topics for negotiation were selected due to their challenging factor and their centrality to contemporary scientific issues and problems that need solving. It was identified that by immersing learners in active investigations of contemporary issues, and engaging them in collaborative discourse, they manage to constructively build on each other's ideas and enhance their learning of scientific concepts. Having students motivated by and engaged in authentic problems that require solving and stimulate their creativity and critical thinking they become key players of the learning process. Students are highly engaged in applying creative solutions while dealing with topics which are critical for their own lives and surface the essential relevance and connection between the curriculum and their everyday life or future career (Johnson, et al., 2009). In this highly motivating and challenging process, students acts as scientists and naturally apply inquiry–based approaches to address the problem under negotiation. They develop research questions, identify, investigate and experiment on various solutions with the help of primary source materials and construct knowledge and build their argumentation discourse in their effort to identify the most efficient and reasonable solution in terms of applicability. The guidance provided by scientific experts not only manages to relate the scientific research with educational environments but also to ensure a high-quality production of findings and to give the process relevance to authentic scientist way of working.

SP aims at strengthening the dialogue between students and science, by engaging students in problem-solving situations involving scientific issues that address current problems. In the simulated parliaments, the participating students become acquainted with parliamentary decision-making processes as well as scientific research grounded on the model of Inquiry-based learning and develop life-long and communicative skills by engaging in dialogue and debate processes aiming at the exchange and sharing of scientific points of view.

During the plenary debate students are given the opportunity to discuss the different sub-topics and exchange their knowledge with the other students in order to collaboratively come up with some final resolutions that will be developed based on their scientific inquiry, evidence gathered and in strong relation to their personal beliefs and attitudes regarding ethical concerns on the 'future of human beings'.

Exemplary Debate Resolutions

In this section, there are presented some possible resolutions for each one of the 5 sub-topics that concern the issue of the 'Future of the human beings' in the form of final points assessed by students and final claims.

- For the sub-topic **'The Human Brain'** students could discuss and assess aspects and problems related to therapies against dementia illnesses and current research and findings on the way the brain works. Some possible resolutions for this sub-topic are:

  Points assessed:

  1. The human brain functionality/generic factors accused for Alzheimer disease
  2. Social/economic/scientific aspect of Alzheimer disease
  3. Legislation concerning patients
  4. Research and /funding /bioethic
  5. Non- invasive methods (electro-egephalograph (EEG), fMRI, PET)
  6. Invasive methods e.g. medication
  7. Prevention
  8. Brain simulation

  Final claims:

  1. Contribute to an action plan comprising the establishment of special centers in charge of prevention and treatment/health care/ mandatory mental examination for high-risk groups
  2. Exploitation of stem cell
  3. Use artificial intelligence to identify innovative remedies
  4. Create a global database with bio signal (EEG, fMRI) for research purposes

- For the sub-topic **"Living and eating healthy – but how?"** students could elaborate and inquiry aspects of organic food, genetically engineered foods and their impact on our health and identify conditions and criteria for eating healthy. Some possible resolutions for this sub-topic are:

  Points assessed:

  1. The Mediterranean diet is very healthy because it is low in fats and calories and contributes to the reduction on heart attacks, cancer and Alzheimer.
  2. We should not consume enriched in ingredients food types, such as food full of salt, but we should consume superfoods, such as beans, broccoli and ginger.
  3. We should consume vegetables, fruits and pulses because they reduce cancer and heart diseases.
  4. We should avoid genetically modified food since we are not sure of its usefulness. Moreover, genetically modified food is not environmentally friendly as it damages the ecosystem by changing the life chain, and the cost of the cultivation is high.
  5. We should avoid the consumption of sweets because they are full of sugar and fats and they can cause obesity and diabetes.
  6. There must be strict laws which will define the harmful ingredients of the food types and also, labels of the ingredients of the food products should be on their package.
  7. Being vegetarians is not healthy because human organism cannot take all the vitamins and proteins needed. Consuming meat is also useful but in small quantities.
  8. Organic food is high in vitamins and low in fats, calories and fertilizers. But it is expensive and consumers cannot afford it. Governments should contribute to the cultivation of it by eliminating taxes.

  Final claims:

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1. We should be conscientious consumers and we should be informed about the dangers of various food types and the benefits of various foods / we should examine the food labels.
2. We should choose products which are environmentally friendly for sustainable development, giving emphasis on food types which have vegetable origins, local products, traditional products and food types which are coming from organic production.
3. We should follow a combination of a balanced diet (Mediterranean diet) accompanied with physical exercise and adequate hydration putting emphasis on water and beverages, and we should be aware of our diet.
4. A conscientious consumption of high in calories food products is needed, the legislation should define the reduction in the selling price of food products which are rich in nutritious ingredients – obesity is a multi-factored sickness.
5. There should be a restriction of the advertisements on harmful food types on behalf of the Mass Media and an increase on suitable stimuli about a healthy diet.
6. School should promote the significance of healthy diet through learning subjects and teaching, and through programmes and educational activities about health education. The school canteens are obliged to comply with the rules set by laws.
7. The genetically modified food, although it is not classified in the characterised as balanced diet food types, is expected to be a topic subject for discussion and research in the long run. Those food types should be marked as genetically modified.
8. The balanced way of leading a life is a total of behaviours, habits and practices which contribute to the assurance and retention of a good physically, mentally and emotionally health and wellness.

- For the sub-topic **"Stem Cells – the potential allrounders?"** students could elaborate on the contradicting issues that surround stem cells, the way our lives can be affected with their manipulation and current limits to their manipulation. Some possible resolutions for this sub-topic are:

  Points assessed:

  1. species of stem cells
  2. features / types of stem cells, the building process of stem cells
  3. comparing species of stem cells
  4. legislation in Greece and Europe
  5. religious issues, social, ethical dilemmas for the use of stem cells
  6. conflicting opinions regarding the use of stem cells
  7. the issue of private vs public
  8. tourism issue for stem cell market

  Final claims:

  1. informing citizens by experts, media / information from school
  2. a common law and a common legal framework in all countries
  3. establishment- foundation of a joint European Commission
  4. use of IPS for further research (using IPS for further research, using morula to produce stem cells
  5. intensified monitoring of private banks / strict controls
  6. combating tourism through tighter controls

- For the sub-topic **"Augmented Human: optimising the human?"** students could discuss and assess aspects and problems related to the current state of optimising the human body by applying prostheses and glasses and the application of new technological advances that are supposed to enhance and modify the human body. Students could reflect on the implications to humans and their skills and the underlying ethical issues that arise. Some possible resolutions for this sub-topic are:

  Points assessed:
  1. The augmented human as a dual approach: addressing the needs of (1) healthy people and (2) people with special needs.
  2. Statistical references to the extent that people nowadays use applications that enable the optimisation and extension of human skills.
  3. Scientific achievements that have been accomplished towards 'augmenting' humans.
  4. Reference to the need for application of scientific developments for medical treatment and serving people with special needs by making their everyday lives easier.
  5. Application of scientific developments for augmented experiences (cultural and educational purposes)
  6. Potential dangers of the 'augmented human' technological applications (privacy loss, violation and exploitation of private data, excessive use, social inequality)
  7. Legal framework: distinction between ethical and legal framework
  8. Considerations for correct use

  Final claims:

  1. Humans' psychosomatic and intellectual improvement through scientific applications

  Distinction of practices: (1) facing health problems and (2) enabling the fullest possible reinforcement of people's skills

  Augmented reality (cultural and educational applications), genome modification

  Reference to the extent of application use

  Positive consequences: (disease treatment, financial and entrepreneurial growth, making daily life easier)

  Strengthening research on issues such as consequences, informing and shaping a moral society

  Reformation of legal framework; distinction between ethical and legal framework

  Are human beings ethically ready?

- For the sub-topic "**Imitating nature**" students could inquire on the functionality and objectives of synthetic biology, the way scientific advances allow the imitation of new biological pieces, gadgets or systems and potential limits that should be placed in such implementations. Some possible resolutions for this sub-topic are:

  Points assessed:
  1. Biomimetics (Examples: Velcroà Burdock, Costume bathesàShark's skin, Robots of explorations, Mobile phone screens)
  2. Synthetical Biology-Advantages: treatment of diseases, improvement of quality of life, information storage etc./ Drawbacks: creation of pathogenic organisms)
  3. Biohacking (Synthetic Biology VS Computers)
  4. E-coli (medicine against malaria, which is cheap thanks to Synthetical Biology)
  5. Maintenance of our data information
  6. Careful study and intervention about the economic consequences that it may bring about, especially in developing countries

7. Europe is in a lower level compared to America concerning Synthetical Biology and more specifically as far as publications and financing research are concerned
8. Imitation of nature should not only be applied in Medicine, but in other fields too

Final claims:

1. Imitation of nature, Synthetical Biology
2. Legislation (it should watch over the developments and the international rules)
3. Security concerning both the genetic data and the lab operation
4. Limits in the use of natural organisms and products of Synthetical Biology/Patents
5. Public discussion between Academics, labs etc.
6. Public awareness campaign
7. Very fast development (Horizon 2020, iGEM)
8. The issue of Bioethics

5 Learning Activities & Effective Learning Environments

Science topic: **Biology** **(Relevance to national curriculum)** **Class information** **Year Group:** **3rd grade of Junior High School and 1st -3rd grade of Senior High School** **Age range:** **15-19** **Sex:** **Mixed** **Pupil Ability:** **Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need?*** **printed evaluation rubrics** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **The preparatory activities will take place in the classroom and in research centers to communicate with experts. Communication with experts will also be realized online. The final debate event will take place in a conference hall to accommodate both participating students but also scientists.** ***Health and Safety implications? None*** ***Technology?*** **Computer and internet access and an online platform to facilitate communication with scientific experts and students from different schools** ***Teacher support? Scaffolding***
Prior pupil knowledge	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **During this scenario, students will** **Month 1: Be attracted to engage with topics addressing the 'Future of Human Being'. They form groups depending on the subtopic they have selected that addresses their individual needs and interests. 1) The Human Brain, 2) Living and eating healthy – but how?, 3) Stem cells – the potential allrounders?, 4) Augmented human: optimising the human and 5) Imitating nature. They search the internet to find relevant information.** **Months 2-3: Acquire a deeper understanding of the topics examined and come up with further questions. Together with their group members make a plan on the elaboration of their arguments based on scientific findings and work on possible solutions.** **Month 4: They contact the scientist to discuss their approach and findings. They become aware of what it's like to work as a scientist and the scientific inquiry. They explore alternative solutions and creative ways to build their arguments.** **Month 5: Prepare for their presentation on the final debate event.**	

Assessment	Differentiation	Key Concepts and Terminology
Students are engaged in inter-workgroup assessment processes throughout the preparation phase. They define the assessment criteria that acts as activator of reflection processes, engaging members of the same group to strengthen their arguments	*How can the activities be adapted to the needs of individual pupils?* **The SP approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realisation. The selection of the topic and the exploration of relevant issues depend on students. During the inquiry phase all students will participate and contribute with relevant to their interest data.**	**Science terminology: stem cells, cognitive impairment, mutants, Biomimetics, bioethics, augmented human, genome modification, prostheses, implants** **Arts terminology: modelling (digital or physical), drawings, videos**

Session Objectives:
During this scenario, students will

Deepen their understanding on issues relevant to the future of human being

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of	✓ Build interest in scientific issues and their explanations/social impact. ✓ engage with open-ended inquiries related to their lives. ✓ use the web to explore the 'future' of human beings. ✓ Understand science as a process not as stable facts	The teacher tries to attract the students' attention by eliciting students' relevant questions or pinpoint unexplored areas to the topic under negotiation.	What do we want to find out/now about these issues? What do you know about these? What if you could predict their

	knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.		What does the 'Future of human beings' mean to you? Which of these issues (human Brain, Living and eating healthy, Stem cells, Augmented human, Imitating nature) would you like to further explore?	implementation in the future?
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	✓ Plan and conduct simple investigation ✓ experiments are conducted to explore different answers following observation, data collection and interpretation,	The teacher identifies possible misconceptions.	Students make a collage of snapshots (taken from videos, journals, etc.) explaining the state of the art with reference to the thematic topic they're exploring. Students may outline evidence in a form of storytelling (eg. How scientific progress in the specific field has affected (improved or deteriorated a person's life).

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	✓ Students engage in analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modeling, etc.).	Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.	Implementing modellisation, facilitating students to express in alternative ways their analysis.
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.	Acts as a facilitator of the process	Provide creative examples/models/ drawings to strengthen their explanations.
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Explore the topic spherically and find connections with other disciplines (eg technology, medicine, engineering). Exploration of new areas according to students' interests	Allows room and enhances connectivism with other disciplines	Creativity in identifying connectivism and providing possible solutions.
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Each group of students produces a report with its findings, presents and justifies its proposed explanations to other groups, the teacher and scientific expert. To facilitate students' editing their scientific report, they are provided with specific guidelines and template for their presentation (eg.	Both scientists and teachers provide guidelines for presentation. Assess pupil's knowledge.	Creative presentation of scientific issues. Design and structure of alternative models/videos (possible future

		Topic, definition of key elements, methodology applied for preparation of the scientific topic, current developments, statistics, legislation, different dimensions of the issue, main arguments in favour and against the issue, key stakeholders, scientists involved, links for additional resources, etc.). The group of students designs a presentation of their claims and alternative models for their illustration.		scientific applications: eg. model of shell houses floating in the sea to face urbanization).
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Become acquainted with parliamentary decision-making processes as well as scientific research grounded on the model of Inquiry-based learning and develop life-long and communicative skills by engaging in dialogue and debate processes aiming at the exchange and sharing of scientific points of view. Students use the argumentation approach to back up their claims by developing warrants and refute their peers' contradictory arguments. The debates' inner element of assessment between the opponents sets the ground for reflection.	Assess pupils' understanding	Depending on the science topic, as a stimulus, pupils present any issues, ethical concerns or consequences surrounding this topic as a story line for a dramatic scene to communicate understanding and conflicting views about the topic.

6 Additional Information

During the students' preparation phase, all participants are supported by experts in the specific fields that share and exchange their ideas and communicate with the students and teachers.

Teachers work with science centre scientists/researchers to create and plan open-ended investigations for their students. The science centre scientists/researchers then support the teachers to carry out these plans in the classroom. Students carry out open-ended practical work that is closely linked to the curriculum and to their everyday experiences of science. Theory is carefully integrated into the practical sessions by the teachers and assessment is realized through observation and conversations with students about the key scientific concepts they are exploring. Application of students' scientific constructs and creative presentation is realized and further assessed in the final debate event.

In addition, during the students' preparation phase, scientific experts support students in their inquiry phase by providing them with links (articles, videos, simulations, etc), guiding them in a holistic exploration of the issue under negotiation.

Some suggested links that experts provided in relation to each thematic sub-topic are the following (further links were provided in students' native language-Greek):

The Human Brain

- P300 Evoked Potential in Patients with Mild Cognitive Impairment
- The clinical utility of the auditory P300 latency subcomponent event-related potential in preclinical diagnosis of patients with mild cognitive impairment and Alzheimer's disease
- Neuropsychological correlates of the P300 in patients with Alzheimer's disease
- Cognitive decline effects at an early stage: Evidence from N170 and VPP
- Electroencephalography and event-related potentials as biomarkers of mild cognitive impairment and mild Alzheimer's disease
- Correlation of auditory event-related potentials and magnetic resonance spectroscopy measures in mild cognitive impairment
- Auditory event-related potentials during target detection are abnormal in mild cognitive impairment
- Human Brain: Facts, Anatomy & Mapping Project
- Virtual reality maze 'predicts Alzheimer's disease'(BBC)
- Online brain training 'helps older adults with everyday tasks' (BBC)

Living and eating healthy – but how?

- Adopt a Mediterranean diet now for better health later
- Healthy Lifestyle: Nutrition and healthy eating
- Alzheimer's: Can a Mediterranean diet lower my risk?
- Mediterranean diet may prevent breast cancer, but there are other reasons to pour on the olive oil
- Genetically modified crops

- Frequently asked questions on genetically modified foods
- Questions and Answers on the Regulation of GMOs in the European Union
- Evaluation of Allergenicity of Genetically Modified Foods
- Safety aspects of genetically modified foods of plant origin
- Guidelines on food fortification with micronutrients
- Food safety
- How safe is your food? From farm to plate make food safe
- Food Today on Nutrition Labelling
- Proceedings: Workshop 'Eat for Health'. European Parliament
- The European Food Information Council

Stem cells – the potential allrounders?

- Stem cell therapy: hype or hope? A review
- Explore Stem Cells
- What are stem cells by MNT
- Stem Cell Basics: Educational cartoon for young learners
- Stem cell controversy
- Stem cell facts by ISSCR
- What is a stem cell? by the Canadian Stem Cell Foundation
- Frequently Asked Questions on stem cells by ISSR
- Presentation: The Nature of Stem Cells
- News about Stem Cells, including commentary and archival articles published in The New York Times
- Pros and cons of stem cell research
- Defining a Life: The Ethical Questions of Embryonic Stem Cell Research
- The Ethical Questions of Stem Cell Research
- Embryonic stem cell research: an ethical dilemma
- Stem cell controversy by Wikipedia
- Ethical Issues on stem cell research
- Ethics of Stem Cell Research
- Stem Book (Harvard Stem Cell Institute)
- Stem Cell Basics (U.S. Department of Health & Human Services)

Augmented human: optimising the human

- "How Technology Transforms Lives"
- The Wearable Era Is Here
- 10 Ways the Next 10 Years Are Going To Be Mind-Blowing
- Is Google working on a cure for cancer?
- Human enhancement (Wikipedia)

- European Parliament. Science and Technology Options Assessment
- Machine 'Learns' Like A Human Brain (NDTV)

Imitating nature

- Biomimetics (Wikipedia)
- Technology that imitates nature (The Economist)

Additional information on the SP approach:

http://www.scienceview.gr/projects/

http://studentparliament.weebly.com/thetaepsilonmualphatauiotakappa941sigmaf-epsilonnu972tauetatauepsilonsigmaf.html

http://www.opendiscoveryspace.eu/community/greek-student-parliament-science-834221

http://pubs.sciepub.com/education/3/12/20/

7 Assessment

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of the SP Demonstrator. For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)'[10] (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

In the context of the SP, the students' qualitative assessment process follows a dual structure: (a) inter-workgroup assessment that acts as activator of reflection processes, engaging members of the same group to strengthen their arguments and (b) external –workgroup assessment that follows the principles and guidelines of a structured parliamentary debate. In the latter case, debate itself features an inner assessment element; the best and most validated (scientifically evident) arguments are the most persuasive (in scientific debates) and inevitably prevail.

In both cases students' development of argumentation skills (Claim, Data, Warrant/Reason, Rebuttal) (Scholinaki et al., 2014; Smyrnaiou et al., 2012) is traced and assessed through evaluation rubrics that have been decided and defined by students themselves. This way, assessment criteria setting acts as a mechanism that triggers and enhances students' in-depth knowledge of argumentation structure and scientific inquiry in order to construct a rational scale of assessment grounded on scientific evidence and argumentation.

For students' structuring an evaluation rubric we suggest the inclusion of all relevant to the SP concept parameters as key aspects of engaging students in the development of scientific arguments: the development of argumentation skills, the assessment of scientific inquiry, the collaboration applied among the members of the same team, the development of communicative skills, communication of scientific concepts, communication with scientists and the development of exchange of information/knowledge skills.

As an exemplary case, we present the following assessment rubric that addresses both types of assessment: inter-workgroup and external –workgroup assessment.

SP's assessment rubric

(a) Development of argumentation skills

- ✓ Having framed the argument, what supporting data do I choose to reinforce my argument? (eg examples, statistics, expert opinions etc.)
- ✓ Argument Rating (Valid, invalid, true, false)
- ✓ Evaluation of supporting data
- ✓ With reference to the counterargument: do I draw material from the same subject-topic? Is there a direct correspondence between argument and counterargument?

(b) Development of dialogic/information/opinion exchange skills

[10] 2011 Shawn M. Glynn, University of Georgia, USA http://www.coe.uga.edu/smq/

- ✓ All sides have equally expressed their opinions?
- ✓ Arguments were relevant
- ✓ Arguments were developed with clarity
- ✓ There was appropriate use of the language code (Avoiding digressions, unjustified peroration, precise argument wording, use of adequate vocabulary/scientific terms, proficiency in documentation)
- ✓ Showing respect for different views
- ✓ Complying with the debate rules (Equal time, equal groups, etc.)
- ✓ Use of non-linguistic elements (Eg gestures, gaze, facial expressions, posture, movements)
- ✓ The climate during the conduct of the debate

(c) Communication with scientists (learning to derive useful information)

- ✓ Inquiry to identify questions to address to scientists
- ✓ Issues and ideas generated after the communication with scientists
- ✓ Acquired knowledge beyond the specific domain after the communication with scientists
- ✓ The communication with scientists has affected:
    - their subject approach
    - scientific thinking
    - use of scientific language (E.g. learned vocabulary, tried to imitate the scientist's speech etc.).

(d) Development of public discourse / parliamentary / communication skills

- ✓ Adoption of different linguistic styles (Eg change in style, intonation of voice, etc.)
- ✓ Successful communication/ utterance of arguments, focus on clarity
- ✓ Challenging and interesting elaboration of arguments

(e) Creative communication

Record two or three examples with reference to creative ways of communication:

• Verbal Communication (eg. examples from other domains)

• Embodied communication of scientific concepts (using any part of the body eg facial expressions, gestures, etc.)

(f) Communication of scientific concepts

- ✓ Acquisition of scientific knowledge
- ✓ Explanation of scientific concepts in a creative way
- ✓ Able to give examples from their personal life
- ✓ Reference of current findings/state of scientific research
- ✓ Connection with other domains

Debate process and Resolution Evaluation

For the actual realization of the final debate, students should be provided with specific guidelines for its procedure, following seven procedural steps (Appendix): (1) Reading out the claims, (2) Defense speech, (3) Attack speech(es), (4) Response to attack speech(es), (5) Open debate, (6) Summarising speech, response to last questions and (7) Voting. Groups of students / Schools that will have negotiated the same topic will have to discuss and decide on the final claims/resolutions that would comprise their final argumentation basis. First, at the beginning of each debate, the proposing committee has the opportunity to read out the committee's claims which are gathered in a structured resolution booklet template. Subsequently, the proposing committee has the opportunity to hold a defense speech and explain the existing resolution and its contents. All committees are given the opportunity to hold one or more attack speeches to elaborate and explain why some of the claims should not be accepted by the delegates. Next the proposing committee has the opportunity to give answers to the attack speech and to allay doubts the delegates might have. During the process, all members of all opposing committees (addressing all 5 subtopics) can raise their hands to address questions or remarks to the proposing committee which is required to give a summarising answer to all of them. Next, the proposing committee will hold a summarising speech and answer the last questions and finally the chair of the debate reads out the claims and asks all delegates to vote for or against a claim.

8 Possible Extension

The SP demonstrator is an exemplary case on how argumentation is situated in science education and its beneficial contribution in advancing students' understandings of the epistemology of science. In order to initiate students into the principles of authentic scientific practice students should be engaged in meaningful and challenging activities and learning processes that are guided by the epistemology of science. A key element that guides SP concept is its flexible nature with reference to the thematic area selection for negotiation and debate. A principle that needs to be pursued is the challenging nature of the topic and the need to address students' interests and be connected with their lives. Therefore, following the SP's guidelines various socioscientific issues can serve as useful contexts for teaching and learning science content by enhancing the acquisition of specific content knowledge and understanding of the nature of science. The topics for negotiation have to be selected according to their challenging factor and their centrality to contemporary scientific issues and problems that need solving. Such topics raise questions of high complexity and are subject to ongoing inquiry, requiring for their negotiation, cognitive reasoning and reflective judgment. In addition, they facilitate the development of multiple, alternative approaches and provide a perspective for incorporating new knowledge into existing knowledge.

Another extension of great beneficial educational outcome - given the communicative nature of the SP's approach - would be to extend the SP's activities at an international level involving the engagement and exchange of scientific ideas and alternative solutions among students of different countries. This way, students will have the opportunity to identify and reflect on potential cultural differences in scientific approaches and share and exchange opinions about ethics that underlie current scientific issues. But most of all, they will acquire a first-hand experience of belonging to an international network/community of peers; inquiring and attempting to solve issues that directly affect our lives.

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APPENDIX

Procedure of the debate

1. **Reading out the claims**
   At the beginning of each debate, the proposing committee has the opportunity to read out the committee's claims which are gathered in this resolution booklet. *(One member of the proposing committee reads out the claims at the lectern.)*

2. **Defence speech**
   Subsequently, the proposing committee has the opportunity to hold a defence speech and to explain the existing resolution and its contents. *(One member of the proposing committee reads holds the speech at the lectern; approx. three minutes.)*

3. **Attack speech(es)**
   Directly after, all other committees have the opportunity to hold one or more attach speeches, provided that the first attack speech does not take up all time. Every committee which has prepared an attack speech can now explain why some of the claims should not be accepted by the delegates. *(One member of an opposing committee; up to three minutes at own seat/via microphone.)*

4. **Response to attack speech(es)**
   The proposing committee has the opportunity to give answers to the attack speech and to allay doubts the delegates may have. *(One member of the proposing committee; up to one minute at own seat/via microphone.)*

5. **Open debate**
   All members of all opposing committees can raise their hands to address questions or remarks to the proposing committee. Up to three questions/remarks are gathered from members of the different committees, before the proposing committee can give a summarising answer to all of them. *(Up to four rounds à three questions/remarks of less than a minute; at own seat/via microphone.)*

6. **Summarising speech, response to last questions**
   The proposing committee holds a summarising speech and answers the last questions. *(Two members of the proposing committee; three minutes at the lectern.)*

7. **Voting**
   The chair of the debate reads out the claims and asks all delegates to vote for or against a claim.

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D3.2.29. LEARNING SCIENCE THROUGH THEATRE

Project Reference:	H2020-SEAC-2014-1, 665917	**Authors:**	Menelaos Sotiriou, Vasiliki Grigoriou, Zacharoula Smyrnaiou, Evangelia Petropoulou (NKUA)
Code:	D 3.22.9	**Contributors:**	
Version & Date:	**V1, 9/5/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics, Physics, Chemistry, Biology

1.2 Type of Activity

School Based – Large scale National Activities

1.3 Duration

5 months

1.4 Setting (formal / informal learning)

Formal and informal. The meetings during the development phase could be within the classroom, the theater of the school (in case that exists), a theater, after class meetings.

1.5 Effective Learning Environment

- Communities of practice
- Arts-based
- Dialogic Space / argumentation
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

Traditionally the body has not been used in education. Every involvement of the body had been consistently excluded from the educational practice, the process of learning and the interaction among students. The notion of Embodied Learning was not known and therefore not acceptable by the educational community such as the teachers and the students. Consequently it was difficult to understand that the body does not solely constitute a means of knowledge, or a mediator, but it also reflects the student's interaction with the environment. (Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016). As a result, until now, students are not usually given the chance to learn scientific concepts through expressing them with their body and by the interaction of their body end the environment.

2.2 Added Value

Through the principles of embodied learning, basic principles of epistemological knowledge and pedagogical theories can be combined, so that the student can utilize his body as a source of knowledge and feel alive and active during the learning process. As a result, the seemingly absent student's body can be activated and used as a communication channel between students. (Arvola, Orlandre & Per-Olof Wickram's In Alsop, 2011).Through embodied learning, each time the human motor-sensory system is involved with his body movements, the stimuli he perceives can be converted into a more stable and powerful memory and cognitive representations (Abrahamson, Gutiérrez, Charoenying, Negrete, & Bumbacher, 2012).
Embodied learning has been linked with the field of Science (Smyrnaiou & Kynigos, 2012). According to Hutto et al. (2015), embodied learning enhanced the understanding and acquisition of skills in physics, technology, engineering and mathematics. Gallagher & Lindgren (2015) investigated the advantages of physical representation of transfer (Chun Hung, Hsiu-Hao Hsu, Nian-Shing Chen, 2015) and found that its representation facilitates the learning outcomes more than just reading the transfer. Furthermore, Lozano and Tversky (2006) argue that gestures can facilitate learning, as they are considered as embodied knowledge. Finally, Novack & Goldin-Meadow (2015) argue that even the gestures can be incorporated into educational activities, especially in courses with symbols, such as Mathematics, Physics and Chemistry. Thus, pupils directly connect their movement, gesture and communication with scientific concepts which they perceive, as embedded in the educational activities (Kynigos, Smyrnaiou & Roussou, 2010).
In the LSTT initiative, the scientific concepts are represented with highly original, imaginative and innovative ways. The embodied learning helps in most cases to describe the concepts in another way, more descriptive. During the dramatization of the students' scenarios, the result was robust when there was a connection between the embodied representation (in its entirety, including the factor of emotion), the scientific concept and verbal description. And it was excellent, if there was extra music or choreography as a representational or embodied system.

It is also worth mentioning that where there was implemented an interdisciplinary and multidisciplinary approach, the scientific concepts were strengthened, as they were in a rich context where, apart from the Art and Science, Literature, Philosophy, Culture (for example this season, or season that Scientist lived) and Society were involved (for example a scientific theatre performance that made reference to the refugee issue, involving harmoniously all previous fields). In this context, science won fr om the embrace with the Art. Science became a vehicle for scientific, social and other messages and challenges. In addition, science acquired emotion and vitality through multiple representations (embodied, verbal, etc.).

Furthermore, in accordance with the constructivist principles, the body is used both inside and outside classroom for experiential learning and is not treated as a place of learning. The principles of Embodied Learning provide answers to questions related to the ways knowledge is constructed by students as they leave behind them the academic model of perceiving knowledge and treat each student as a whole, while they view everyone's body as a tool for knowledge construction and as a knowledge carrier (Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E.) Moreover, constructionist learning involves students drawing their own conclusions through creative experimentation and the making of social objects.
Regarding the argumentation approach, by engaging students in argumentation processes provides them with a better insight into the nature of scientific enquiry and the ways in which scientists work. This enculturation in the scientific discourse (Driver, et al., 2000; Duschl & Osborne, 2002; Osborne, 2010) can subsequently lead to epistemic improvement in pupils' knowledge (Smyrnaiou, et al., 2015). The argumentation process in this case might be the exchange of ideas and dialogue when the script of the theatrical performance is developed.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Learning Science Through Theatre (LSTT) approach is to give the opportunity to **high school students to stage a play and dramatize scientific concepts and knowledge from the material being taught in schools.**

The LSTT's domain specific objectives are to:

- Get students interested in science and research through theatrical play
- Teach students how to develop a theatrical script, relevant to a scientific topic
- Initiate the development of a theatrical performance from students, regarding a scientific topic
- Initiate contact between students and other professionals (for example directors and musicians)
- Bring schools closer to local community
- Engage parents and the general public into schools' happenings and events
- Build National-wide student networks
- Open the school to the community and involve all the stakeholders.

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop abilities necessary to do scientific inquiry
- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- design and conduct theatrical scripts relevant to scientific concepts and issues
- use technology to improve investigations, communications and the development of theatrical performances and videos
- formulate and revise scientific scripts exploiting creativity and imagination
- recognize, analyze and imagine alternative explanations and models
- communicate a scientific argument or issue in a creative way

- develop lifelong learning skills
- develop attitudes befitting a scientific ethos
- link with science and society in a personal context

3.2 General skills objectives

In the context of the LSTT, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art (students will create a multi-disciplinary artistic performance -Science Theater- which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- Develop spirit of cooperation and teamwork
- Connect the science classroom with professionals, parents and local communities

More Specifically:

- Students will learn and build knowledge about scientific concepts from the curriculum of their courses
- Students will become acquainted with the concept of learning science creatively through Science Theater. They should be aware of what science theater is and how it will help them deepen their science knowledge and express themselves creatively. They should also be specific about key concepts they will be focusing on.
- Students will gain knowledge and experience with group-work in which various groups will create a script, scenography, costumes, music and a video composition. The script should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.
- The students should be able to describe fundamental concepts concerning their chosen topic. Students will learn to realize common impulses between discipline knowledge in both science and arts by performing a multi-disciplinary artistic performance which demonstrates and deepens scientific and emotional understanding. Throughout the initiative, pupils will learn to make their own decisions during inquiry processes, make their

own connections between questions, planning and evaluating evidence, and reflect on outcomes.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to high school students to stage a play and dramatize scientific concepts and knowledge from the material being taught in schools. In this way, students learn science in a creative way.

In the LSTT project, participated 30 schools both public and private. The project is addressed at students between 12 and 16 years old. At least one teacher is responsible for each school/participation (2 teachers are recommended, one from art and one from science). Students and teachers select a science theme that would like to develop as a theatrical performance. In this way, it is given the opportunity to students to inquire about scientific concepts and issues of their interest and express their findings in creative ways, such as the development of theatrical scripts, costumes, scenery, choreography, etc.

The LSTT demonstrator aims at the enhancement of the students' cognitive involvement, their representation of scientific content using their cognitive processes, the students' sensorimotor involvement using their bodies or gestures, their emotional involvement, the social interaction and communication between them, the use of past experiences and the creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors, their brain, body and emotion coordination and finally the holistic use of their personality and their motives.

4.2 Student needs addressed

The LSTT project includes the development of authentic theatrical scenarios which are performed by the students and are in accordance with their interests and cognitive load. Students develop research questions, identify, investigate and experiment on various scenarios and scripts and construct knowledge. The topic for the development of the theatrical play is selected by the students. This freedom of the topic selection is a challenging factor for students in order to get immersed in active investigations of scientific issues, and be engaged in collaborative discourse and creation. As a result, students manage to constructively build on each other's ideas, enhance their learning of scientific concepts, co-create and perform theatrical plays. The co-creation engages them in meaningful activities in authentic environments and the theatrical performance helps them learn end express scientific concepts using their body, their gestures, etc. Embodied Learning leads students to the most successful representation of scientific concepts, enables the connection of student to modern forms of Art while even the unconscious movements performed by the students may be indicative of the degree of appropriation and embodiment of scientific concepts. During the implementation of LSTT, students seem to be able to understand the key features of each notion, using scientific terminology and simple vocabulary at the same time, to reliably describe notions and to use their past experience so as to describe scientific knowledge. Additionally, successful rendering of meaning is also possible both through verbal and through non-verbal communication.

Furthermore, collaborative learning is supported through Embodied Learning, which facilitated communication among students. Students' creativity and imagination is also evident in most LSTT's theatrical performances (Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016).

Finally, the guidance provided by professionals, not only manages to relate science with art, but also ensures a high-quality production of scientific theatrical play.

5. Learning Activities & Effective Learning Environments

Science topic: Mathematics, Physics, Biology, Chemistry **(Relevance to national curriculum) Greek Junior and Senior high School curriculum** **Class information** **Year Group: 1st – 3rd grade of Junior high school and 1st-2nd grade of Senior High School** **Age range: 12-16** **Sex: both** **Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** **material for scenery, costumes, laptop, video editing tools, musical instruments, teleconference platform** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The preparatory activities will take place mostly in the classroom, but also at local community organizations, such as a city hall, a local police department, etc. Preparation will also take place at students' homes, with the contribution of their parents. Communication with professionals will be realized in person at schools, but also online. The final event will take place in a conference hall at National and Kapodistrian University of Athens, but also at a Science Center and Technology Museum, Thessaloniki. Finally, participations with video recorded theatre performances will be available online.** ***Health and Safety implications? none*** ***Technology?* Computer and internet access and an online platform to facilitate communication with professionals** ***Teacher support?* scaffolding**
Prior pupil knowledge	

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***
During this scenario, students will
Month 1: Be attracted to engage with scientific topics and theatrical techniques. They form a general group, depending on their interest in participating to the project. They search the internet to find relevant information about the scientific topic/issue they have chosen.
Months 2-3: Acquire a deeper understanding of the topics examined and come up a basic theatrical script. Together with their group members make a plan on the elaboration of the preparation about the theatrical play and split into subgroups (main actors, students responsible for script, for direction, for costumes, for choreography, for lights, etc). They form stories/scenarios based on scientific findings and work on possible theatrical scripts, scenery, costumes, music and choreography.
Month 4: They contact the professionals (director, musician and pedagogist) to discuss about their script, music and direction. They become aware of what it's like to work creatively, using their imagination and their findings in order to compose innovative theatrical performances. They explore alternative solutions and creative ways to express their arguments.
Month 5: Prepare for their and rehearsals, approximately one week before the 2-days final Theatre Event.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Students are engaged in inter-workgroup assessment processes throughout the preparation phase. They define the assessment criteria that acts as activator of reflection processes, engaging members of the same group to strengthen their arguments	*How can the activities be adapted to the needs of individual pupils?* **The LSTT approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realisation. The selection of the topic to be dramatized and the exploration of relevant issues depend on students. During the inquiry phase all students will participate and contribute with relevant to their interest data.**	**Science terminology:** **Maths, Geometry, Physics, Newtonian physics, nuclear physics, astronomy, big bang theory, biology, criminology** **Arts terminology:** **Theatre performance, direction, scenery, costumes, choreography, music, video editing**

Session Objectives:
During this scenario, students will deepen their understanding on scientific concepts and phenomena, using their creativity and imagination

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Build interest in scientific issues and their explanations/social impact. engage with open-ended inquiries related to their lives. use the web and watch videos to explore the selected scientific topic/issue	The teacher tries to attract the students' attention by eliciting students' relevant questions or pinpoint unexplored areas to the topic under negotiation.	
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students investigate on the science theatre design and implementation. They are divided into groups: Script/directing group: Investigate characters and generate ideas for dialogues/actions.	The teacher identifies possible misconceptions.	

		Actor group: Investigate characters and work on performance in collaboration with script/directing group. Music group: Generate musical ideas which correspond to the script. Dance group: After consulting with script/directing, actor and music groups, generate choreography ideas to incorporate in the play. Set/costumes group: Generate ideas after consulting script group and collect materials. Video group: Generate ideas after consulting script group and collect or create video clips.)		

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students engage in analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modeling, etc.).	Acts as a facilitator of the process	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.	Acts as a facilitator of the process	Provide creative theatrical scenarios/scripts to strengthen their explanations
Phase 5: **CONNECT: students connect explanations to scientific knowledge**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Explore the topic spherically and find connections with other disciplines (eg arts, theatre, music, technology).	Allows room and enhances connectivism with other disciplines, such as arts, theatre	Creativity in identifying connectivism and providing possible solutions

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		Exploration of new areas according to students' interests	and music. Teacher also communicates with professionals (director, musician and pedagogist)	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate with professionals (director and musician) in order to get help about their scientific scripts, the direction and the music. Students communicate their inquiry findings by implementing a science theatre performance		Rehearsals of theatrical performances and final 2-day science theatre event

Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Discuss specific issues (stage design, music composition, group dialogue, ethical decision-making regarding inclusion of all students in the creative process, etc.)	Teacher balances the outcomes of the creative educational process with the assessment features of the curriculum	

6. Additional Information

During the students' preparation phase, all participants are supported by professionals in the field of theatre and arts (director and musician) and teachers are supported pedagogically by pedagogists. These professionals share and exchange their ideas and communicate with the students and teachers in order to support them to the whole process. If necessary, visits of the organisers to the schools during the project are organized, in order to help and advise teachers and students during the development, preparation and rehearsal periods. Furthermore, online and in-person workshops are implemented for the teachers to guide and support them. Moreover, the Open Discovery Space Platform (ODS - http://www.opendiscoveryspace.eu/el/community/learning-science-through-theater-2-834218) is an online platform where teachers and students have the opportunity to share their opinions and their educational resources.

Participants that are not able to participate in the two areas for live performances (Athens and Thessaloniki), have the chance to film their performances and send them to the organisers. These films are evaluated as a different category.

Additional information on the LSTT can be found at:

- http://www.scienceview.gr/project/lstt/?lang=en
- http://lstt2.weebly.com/
- https://www.facebook.com/learningsciencethroughtheater/
- http://www.opendiscoveryspace.eu/el/community/learning-science-through-theater-2-834218

So pictures are provided below.

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7. Assessment

The performances are evaluated by evaluation panel of academics, science teachers, directors, actors, musicians (50%) and 1 teacher and 1 student from each school (50%). Awards for different categories are given to the participating schools. These include:

- Best Performance as a whole
- Best Script
- Best Direction
- Best Soundtrack
- Best stage sets and costumes
- Best Choreography

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of the LSTT Demonstrator.

For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)' 11 (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

Regarding qualitative assessment, each group of participating pupils will be provided with a **questionnaire** that includes questions about their level of enjoyment, comparisons to more traditional teaching methods, etc. More specifically, since "Entertainment" is an important part of a theatrical performance, it is worth mentioning that students will retain their interest throughout and will enjoy the whole procedure. (Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016)

The questionnaire will also include questions based in three categories relevant to Embodied Learning: a) representation of scientific content/generation of meaning, b) communication between students, c) entertainment of the audience, while students dramatize scientific scenarios which take into account both the teaching of sciences and theatre techniques (Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016).

Each group of participating pupils will be expected to conduct a **report** about their experience from the first moment of involvement until the implementation of the action, recording on how they represented scientific concepts, what theater techniques they used, significant episodes that demonstrated their creativity (imagination, innovation, uniqueness), their improvisation and

[11] 2011 Shawn M. Glynn, University of Georgia, USA http://www.coe.uga.edu/smq/

also some significant moves (embodied movements) that they used for the representation of scientific knowledge. At this point, it is worth mentioning that the procedure that is followed during Embodied Learning is gradually escalating. During the first stage, the student may not proceed to a movement related to the representation of concepts. During the second stage, movements are produced sometimes unconsciously or even as the result of imitation while during the third stage the students are asked to think of ways of representing the suggested content. During the final stage which is also the most important one, students apply the newly acquired knowledge to new environments, through dramatization (image/interactive theatre) or role play, where they represent the scientific concept not only verbally or by using body movements, but also by participating both mentally and emotionally to the extent of embodying this new knowledge. (Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016)

Teachers are expected to fill an observation **rubric**, which is significantly important about the scientific and pedagogical evaluation of the whole procedure. This rubric includes the following questions:

1. What was the *starting point* for writing of the script? Did you use an existing script? Did you start from the theatre techniques or from the scientific content? Describe.

2. Record two or three important events that demonstrate the *creativity* of the students (the concept of creativity is associated with imagination, originality, innovation).

3. Was *embodied learning* obvious during the dramatization of the scientific concepts? In which way? Tick the cells of the following table.

Characteristics of embodied learning	**Representation of scientific content**		**Communication**		**Entertainment**		**Random, uncategorizable movements**
	Understanding	***Imlementation, Fidelity***	***Successful transfer of meaning***	***Interaction/ Collaboration***	***Interest/ Fun***	***Clarity of Roles***	

Isolated Gestures							
Full body movements							
Emotional attachment							
Facial expressions							

4. Outline the students' *cognitive path/process* from the first moment until the implementation of the first sketch, indicating 2-3 examples in each category:
   A. Initial ideas that remained constant

   B. Initial ideas that evolved

   C. Initial ideas that were rejected

   D. Important ideas that arose along with the action
5. Indicate *theatre techniques* or other techniques that you implemented/exploited.
6. Were there any points where students *self-corrected* the way that they would represent the concept?
7. Were there any points where students *improvised*? Indicate 2-3 important examples where students deviated from what was agreed, but the final result was equally excellent.

The above rubric is then expected to be analysed using qualitative methodologies, resulting in three different categories of analysis:

- The category of "Representation of scientific context/ meaning generation"
- The category of "Communication
- The category of "Entertainment"

(Smyrnaiou Z., Sotiriou M., Georgakopoulou E., Papadopoulou E., 2016)

Finally, the dramatized scenarios are expected to be **observed** by a scientist and an artist, who will then analyze the data collected from their observation and they will connect them to the characteristics of Embodied Learning. Thus, a cross analysis of the dramatized scenarios will be implemented from two different points of view (one scientific and one artistic), resulting in a merge into one final analysis.

8. Possible Extension

Through the LSTT project, students learn about scientific concepts by following the inquiry cycle and creating their own theatrical performances. Engaging parents and local community to the preparation of the theatrical scripts, costumes, etc is one possible extension. Furthermore, The LSTT project is a large scale national activity. By encouraging teachers and students from other countries to participate to the project, it could become a large scale international activity, where students from different countries communicate and share their creative ideas, their own scientific understandings and their own cultural elements.

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D3.2.30. Inquiring the Ghost particles

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Zacharoula Smyrnaiou, Menelaos Sotiriou, Evagelia Petropoulou, Zois Assimakopoulos, Vasiliki Grigoriou (NKUA)
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1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Arts

1.2 Type of Activity

The specific activity is a combination of:

(a) School based and

(b) School – research centre collaboration

As it is developed the activity can be characterised as a Small scale Activity at a Local level

1.3 Duration

1 month

1.4 Setting (formal / informal learning)

Both formal and informal. The demonstrator involves classroom inquiry activities and virtual visits to CMS.

Formal and Informal learning settings

- Classroom
- Research center, art center (physical visit or virtual)
- The 'Neutrino Microworld' (logo-based)
- HYPATIA event analysis tool written by IASA
- Open Discovery Space portal (http://www.opendiscoveryspace.eu/community/greek-student-parliament-science-834221 - as a collaboration area) if several schools, national or international are involved.

1.5 Effective Learning Environment

- Simulations (digital/physical)
- Arts-based
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience

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2. Rational of the Activity / Educational Approach

2.1 Challenge

Student's basic knowledge, concerning the way that the world is structured, begins, in a micro level, with basic concepts of molecules and atoms. Taking this as the starting point for our journey in the world of the subatomic particles, we aspire to introduce students to the most recent discoveries in the particle physics research – "The Ghost Particles, neutrinos". The selection of this challenging topic is not guided only by the recent '2015 Nobel prize award in physics for the discovery of neutrinos' oscillations' but also for the still unsolved mysteries of their identity and all the potential scientific breakthroughs that their exploration, by next generation scientists, may induce.

The main goal of the specific demonstrator is to incorporate a series of activities which will allow us to create an engaging learning environment in classroom. Students will be given the opportunity to inquire and learn the history of particle physics from ancient history until present and acquire basic concepts and principles guiding the field of particle physics, beyond the school curriculum.

The demonstrator involves a set of interactive activities guided by the principles of IBSE approach that aspires to engage students in an authentic scientific discovery process. Students will be involved in the construction of a timeline regarding the history of particle physics, exploring and reflecting on the cultural aspects that prevailed in each era as well as the adopted way of scientific inquiry for each time period. Students will also be challenged to project the acquired knowledge and scientific concepts through dramatization activities by applying experiential modelisation techniques that enhance deep understanding of learning 'objects' (Smyrnaiou, et al., 2016; Smyrnaiou & Kynigos, 2012).

Students will have the opportunity to become part of the greatest scientific adventure in CERN and communicate with scientists through the ATLAS virtual visits. This way, they receive a tour of the control room, get answers to their questions but they also examine how professional researchers work in the field of particle physics. In addition, students will also be engaged in hands-on experimentation through interactive simulations and collaboratively perform realistic high energy physics data analysis, using the HYPATIA event display tool (Kourkoumelis & Vourakis, 2014) which uses data collected from the LHC running.

Finally, students' understanding of the scientific concepts/theories under negotiation is projected through their engagement in creative artistic mediation such as role playing/dramatization, drawings of subatomic particles featuring their principles, posters, digital storytelling, short theatrical plays, etc.

Through these interactive activities we anticipate that students will be involved in an engaging learning environment in which complex scientific concepts will emerge in a way that additional pedagogical value will arise during the educational process.

2.2. Added Value

The Greek School curriculum in Physics addresses very basic concepts regarding particle physics, limited to the identification of the three subatomic particles; neutrons, protons, electrons. Students' limited engagement in the field of particle physics not only deprives them of the most magical and challenging aspects of physics and current scientific research but it results in students having misconceptions about the fundamental aspects of the world and what it is made of. Students' illiteracy in terms of basic aspects of the subatomic world also hinders their personal engagement in tracking and following scientific endeavors and breakthrough discoveries that are currently taking place in scientific centers such as CERN; a key element that would enhance their linking with science and society in a personal context.

The 'Inquiring the Ghost Particle' demonstrator applies the Inquiry Based Science Learning (IBSE) approach as an effective educational framework that aspires to engage students in an authentic scientific discovery process. Students' engagement with scientific concepts/theories of the particle physics is grounded on the process of scientific reasoning and construction of scientific knowledge based on the ground premises of mental exploration, testing hypotheses, data collection and consequent discursive exploration and analysis. This way, students will manage to face their misconceptions and learning derives as the product of the cognitive interaction and conflict between intuitive learning and new cognitive schemas and ideas that are structured by challenging our intuitions while engaged in scientific inquiry situations (Smyrnaiou, & Evripidou, 2012). In their effort students will be supported by computer based models and simulations that contribute to the explanation and assimilation of demanding scientific concepts (Smyrnaiou, et al., 2012). Students' engagement with the HYPATIA event display tool, negotiating realistic high energy physics data collected directly from the LHC running as well as students' design of their own simulations projecting neutrino decays, facilitates and enhances students' immersion in the scientific inquiry approach (Zacharia, 2003). According to Lemke (2009) *'…to learn science is to learn how to have some degree of participation in this process of invention and discovery'.*

A key element of this demonstrator is students' creative manipulation of the acquired knowledge. Students' engagement in role playing/dramatization is grounded on physical representation of transfer approach (Hung, et al., 2015) which directly connects physical movements and gestures with students' perception and deep understanding of scientific concepts (Kynigos, Smyrnaiou & Roussou, 2010). In addition, students' hands-on engagement with drawings and development of digital storytelling, addressing the underlying principles that guide the subatomic world, projects their perception and understanding of the newly acquired scientific concepts. The creative manipulation of scientific concepts enhances students' deep reflection of the underlying

principles/theories and sets a prolific ground for alternative thinking and connectivism with other domains. This way students are engaged in processes that bring into the foreground their own conceptualizations and ideas regarding scientific ideas.

In addition, the demonstrator has been realised through the implementation of the 'Content and Language Integrated Learning' (CLIL) approach with a main aim to highlight the communicative approach (dialogic approach, argumentation) adopted in foreign language teaching to enhance students' inquiring and reflective process while collaboratively negotiating scientific concepts (Coyle, 2006; Lemke, 2009; Marsh, 2012). Furthermore, students had the opportunity to realise their inquiry by using and exploring first source material and acquire the scientific vocabulary that is currently used by the scientific community.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the 'Inquiring the Ghost Particle' demonstrator is to **improve pupils' enjoyment of and attainment in science via inquiry-based investigations**. The demonstrator's objective is to introduce students to the most recent discoveries in the field of particle physics research and enhance their development of inquiry skills by engaging them in reflective processes on the way of scientific inquiry throughout the history of particle physics. This is achieved by providing opportunities for students to engage in hands-on inquiry activities and communicate and discuss key scientific concepts and processes with experts in the field.

The 'Inquiring the Ghost Particle' demonstrator's domain specific objectives are to engage/enhance students':

- Inquiry process of scientific concepts
- Developing competences of critical / analytical thinking
- Experiencing scientific concepts and phenomena that are not visible on a macro level
- Access to most recent researchers' work in particle physics
- Involvement in scientific data analysis
- Development of collaborative skills
- Understanding and involvement in the interaction of Science and Art

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop abilities necessary to do scientific inquiry
- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- use technology to improve investigations and understanding of scientific concepts
- recognize, analyze and imagine alternative explanations and models
- develop lifelong learning skills
- develop attitudes befitting a scientific ethos
- link with science and society in a personal context

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3.2 General skills objectives

In the context of the 'Inquiring the Ghost Particle' demonstrator, the general skills objectives addressed are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art (students will design decay simulations in software, create drawings of elementary particles/neutrinos, perform short theatrical plays) which engages students in experiential modelisation and facilitates deep understanding of complex concepts/theories.
- Develop spirit of cooperation and teamwork
- Connect the science classroom with state-of the-art research and scientific community

More Specifically:

- Students will have the opportunity to approach basic principles and concepts of the subatomic world *"The Standard Model Of Particle Physics".*
- Students will have the opportunity to explore the world of particle physics during their collaborative involvement with interactive computer based simulations and models.
- Students will examine how professional researchers work in the field of particle physics (virtual visits / video demonstrators).
- Students will attempt to approach science from a different perspective, through the combination of science and multiple aspects of art.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to high school students to learn about established principles regarding Particles Physics and learn about recent advances in physics research. The complex concepts that feature particle decays and subatomic structure will be presented to students through challenging and inquiry–based learning activities, such as interactive simulations and creative experimentations, artifacts and drawings, aiming to raise students' interest in the process of physics-based discovery and strengthen their inquiry skills in pursuing knowledge in an autonomous way beyond the school curriculum.

The 'Inquiring the Ghost Particle' demonstrator has been applied to 1 public school, addressing junior high school students between 12 and 14 years old. Three teachers of different disciplines were involved in the realization of the demonstrator: (1) a physics teacher, responsible for guiding students, regarding scientific concepts and supervising the learning material, (2) a teacher of English for the realization of the CLIL approach, who guided students in their inquiry through first source material and (3) a teacher of Arts who provided students with drawing techniques to facilitate their effective attributing of their conceptual scientific ideas. The demonstrator was realized within four weeks -a two hour extra-curriculum lesson each week- and resulted with students' presentations on the thematic area of the history of particle physics, the principles of neutrinos and the way current detectors work. In addition, students realized an artistic exhibition with their work of arts that projected their conceptions of the sub-atomic particles and their corresponding principles.




4.2 Student needs addressed

In the 'Inquiring the Ghost Particle' demonstrator the topic for negotiation was selected due to its challenging factor and its centrality to contemporary scientific issues and problems that need solving. It is applied as an extension to the curriculum of physics and provides students the opportunity to approach basic principles and concepts of the subatomic world. By immersing learners in active investigations of contemporary issues, and engaging them in collaborative discourse, they manage to constructively build on each other's ideas and enhance their learning of scientific concepts. Having students motivated by and engaged in authentic problems that require solving and stimulate their creativity and critical thinking they become key players of the learning process.

Students act as scientists and naturally apply inquiry–based approaches to address the problem under negotiation. They develop research questions, identify, investigate and experiment on various solutions with the help of primary source materials. In addition, the demonstrator highlights the significance of interconnecting *science, culture and creativity* and enhances students' reflection process on the scientific inquiry applied throughout the history of particles physics. A key element in the demonstrator is students' linking of science and society in a personal context and their engagement in the creative manipulation of the acquired scientific knowledge.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics- Art (Relevance to national curriculum) Extension to Greek Junior High School physics curriculum Class information Year Group: 1st – 3rd grade of Junior high school Age range: 12-14 Sex: Mixed Pupil Ability: Mixed eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **PC labs** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **The activities will take place in the classroom and there will be a communication with scientists through the ATLAS virtual visits.** *Health and Safety implications?* **None** *Technology?* **Computer and internet access** *Teacher support?* **Scaffolding**
Prior pupil knowledge **Basic concepts regarding particle physics; identification of the three subatomic particles: neutrons, protons, electrons**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Week 1: Brainstorming and Inquiry phase: Discuss and document their initial ideas about how the world around us (blocks of matter) is constructed. This brainstorming activity is followed by a short inquiry phase concerning subatomic particles. The initial activities are followed by a presentation of the standard model from Cern's researchers, bridging the gap between high-school curriculum and modern physics research.

Week 2: Hands-on experimentation phase: At the end of this phase students have the opportunity to experiment with an interactive simulation relevant with the topics discussed earlier (elementary particles) which gives them the opportunity to compare, combine and make assessments related to the knowledge and the concepts they acquired through the process. The use of computer based simulations and half-baked microworlds will give the students the opportunity to examine scientific data and historical facts related to the discovery of neutrinos and particles decay process. The simulations are logo based or based on Flash or Unity to facilitate both students' and teachers' access to operational and programming functions and interventions that will be guided by the scientific issues under negotiation.

Week 3: Students' simulation-based design phase & Virtual visits phase: Following this activity the students are encouraged (under the guidance of their tutor) to create their own simulation by using simple premade "blocks" of logo code. The students will also have the opportunity to take a remote tour at relevant main experiments at LHC (CMS and ATLAS) through Virtual Visits to their Control Centers and even to the underground cavities. Additional to the above they can watch a video related to WIPAC 'S "Ice cube" infrastructures.

Week 4: Students' artistic implementation of scientific concepts: Through the activities described above students will be encouraged to engage in multiple assignments that combine art and science (drawings, posters, comics and short theatrical plays, etc.). Their final works of arts are exhibited in their school's main hall.

Assessment	Differentiation	Key Concepts and Terminology
Students' deliverables	**The 'Inquiring the Ghost Particle' approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realization. The selection of the topic and the exploration of relevant issues depend on students. During the inquiry phase all students will participate and contribute with relevant to their interest data.**	**Science terminology: subatomic particles, neutrinos, standard model**

		Arts terminology: drawing, dimension, shade, scale, video, digital storytelling, dramatization (role playing)

Session Objectives:

During this scenario, students will **deepen their understanding on scientific concepts and phenomena regarding particle physics and the way of scientific inquiry and face their misconceptions**

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches	✓ Build interest in the scientific issue ✓ engage with inquiry related to current scientific reserach ✓ use the web to explore and examine their initial ideas ✓ Understand science as a process not as stable facts	The teacher tries to attract students' attention by eliciting students' relevant questions or pinpoint unexplored areas to the topic under negotiation. What is the universe made of?	What do we want to find out/now about these issues? What do you know about these?

	to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.		Which are the fundamental particles? How long have people been thinking about the fundamental particles? Which great discoveries/findings have led us to current knowledge? Which was the scientific method that characterized each era (in the history of particle physics)? How many different types of matter particles exist? What are the 'anti-particles'?	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in	✓ Plan and conduct simple investigation ✓ Collaborate to make a particle physics timeline ✓ Search evidence to define the scientific method of each era	The teacher identifies possible misconceptions.	Create drawings to illustrate the history of particle physics and identify milestones

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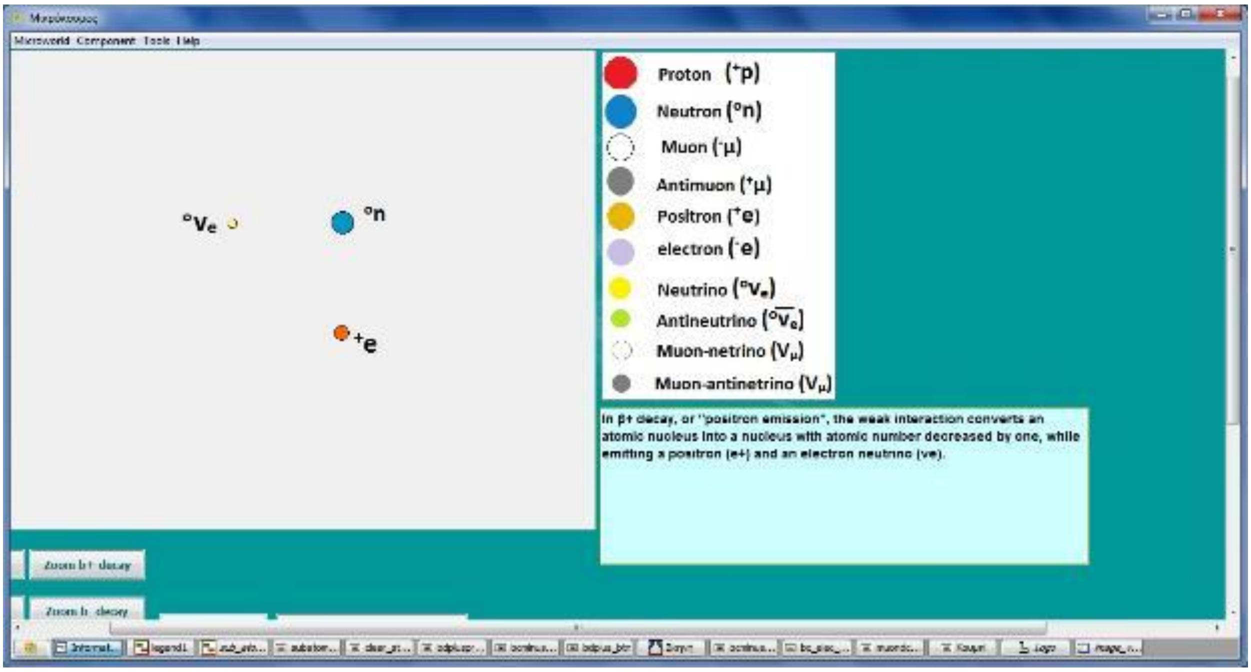
	empowering pupils to generate, question and discuss evidence.			
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students engage in analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modeling, etc.).	Acts as a facilitator of the process	Introduce the debate topic, regarding the scientific way and what is currently accepted. Can philosophical ideas be characterized as scientific method?
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.	Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.	Provide creative examples/models/ drawings to strengthen their explanations.

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students engage in hands-on experimentation with interactive simulations They design their own decays and thest their hypotheses and previous explanations Exploration of new areas according to students' interests	Allows room and enhances connectivism with other disciplines	Creativity in identifying connectivism and providing possible solutions.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an	Realize virtual visit with ATLAS and communicate with scientists. They ask questions and present their own understanding. They engage in creating artistic drawings that project their conceptual understanding of the scientific concepts.	Acts as a facilitator of the process. Assess pupil's acquired knowledge.	Artistic projection of scientific concepts through role-playing, digital storytelling and drawings.

	ethical approach to working scientifically.			
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	They reflect on their initial misconceptions and the way they were faced. Discuss on current research findings and their impact on our lives. Elaborate on other scientific issues of current interest that they would like to explore.	Highlights on the importance of an adopted way of scientific way. Challenges students with questions on theoretical physicists and experimental physicists.	Why is the current way of scientific inquiry sustainable? Students are invited to imagine the consequences in the case of unavailability of a common ground for scientific inquiry among the scientific community.

6. Additional Information

In the context of the 'Inquiring the ghost Particle' demonstrator, students are engaged in hand-on experimentation with computer-based simulations. The 'Neutrino Microworld' (logo-based) applied in this demonstrator is an interactive simulation, projecting 'positron emission' and a b-decay (See figure below). In this simulation students are provided with background information on the standard model and the subatomic particles and they are engaged in making hypothesis, observations in particles' activity during particles decay process. Through this interactive simulation, learners have the opportunity to compare, combine and make assessments related to the knowledge and the concepts they acquired through the process. The representational aspect of the simulation contributes to the explanation and assimilation of demanding scientific concepts.



Besides the classroom activities, students will participate in the ATLAS virtual visits during which they will have the opportunity to communicate with scientists and examine how professional researchers work in the field of particle physics.

In addition, students may collaborate and communicate further their ideas with schools form other areas of the country or even aboard, through the Open Discovery Space Platform (ODS - http://www.opendiscoveryspace.eu/el/community/learning-science-through-theater-2-834218) which is an online platform where teachers and students have the opportunity to share their opinions and their educational resources.

Some suggested teaching/learning resources:

- ✓ https://www.youtube.com/watch?v=V0KjXsGRvoA Video CERN: 'The Standard Model of Particle Physics'
- ✓ http://pdg.web.cern.ch/pdg/cpep/startstandard.html 'The Adventure of particles': Interactive Simulation
- ✓ https://www.youtube.com/watch?v=nlv06lSAC7c quarks
- ✓ https://www.youtube.com/watch?v=E99HuhaXO08 leptons
- ✓ https://www.youtube.com/watch?v=WzHSI-NlYUI -Announcement of the Nobel Prize in Physics 2015
- ✓ https://www.youtube.com/watch?v=nkydJXigkRE -Why neutrinos matter
- ✓ https://www.youtube.com/watch?v=m7QAaH0oFNg How you represent a neutrino
- ✓ https://www.youtube.com/watch?v=qgg4YUnLL3Y The Sun's Neutrino Heartbeat
- ✓

Demonstrator's resources

http://atlas-live-virtual-visit.web.cern.ch/atlas-live-virtual-visit/

https://wipac.wisc.edu/ghostparticle

http://etl.ppp.uoa.gr/_content/download/index_download_en.htmhttp://hypatia.phys.uoa.gr/

http://popplet.com/app/#/3092760

https://www.glogster.com/

https://animoto.com/

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7. Assessment

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of the Demonstrator. For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)'12 (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

In the context of the 'Inquiring the Ghost Particle' demonstrator, the students' qualitative assessment process was evaluated through worksheets, collaborative design of artifacts and artistic drawings and final presentations of the scientific ideas under negotiations. In addition, to assess the effectiveness of the demonstrator with the implemented CLIL approach, there were used two questionnaires: (1) a pre-evaluation questionnaire and (2) a post evaluation questionnaire.

I. Pre –evaluation questionnaire

Fundamentally Speaking
"What is the world made of?
What holds it together?"

Democritus (460-370 B.C.)   Wolfgang Ernst Pauli (1900 –1958)

[12] 2011 Shawn M. Glynn, University of Georgia, USA http://www.coe.uga.edu/smq/

Takaaki Kajita (b.1959)

Arthur Bruce McDonald (b.1943)

People have asked these questions for thousands of years. But only recently has a clear picture of the "building blocks" of our universe been developed. The scientists who have developed this picture work in an exciting and challenging field called high-energy particle physics. Their discoveries are summarized in the chart, Standard Model of Fundamental Particles and Interactions.

How much do you know about the latest theories and research on these ancient questions? You can find out by reading each of the statements below and placing a check mark in the proper box on the next page to indicate whether you agree or disagree.

A) Knowledge testing

Challenges **Put a tick in the box of your choice and make sure you provide explanations.**	**Agree**	**Disagree**
1. There are subatomic particles that have no mass and no electric charge.		
Explanation:		
2. Antimatter is science fiction and not science fact.		
Explanation:		
3. The smallest components of the nucleus of an atom are protons and electrons.		
Explanation:		
4. Gravity is the strongest of the fundamental forces of nature.		

Explanation:		
5. Scientists never state a theory before it is proven.		
Explanation:		
6. Gravitational forces are one of the accepted four fundamental forces of the universe.		
Explanation:		
7. Another name for neutron is neutrino.		
Explanation:		

B) Personal beliefs in scientific methodology

In the following table state the degree of agreement/disagreement with the following statements by placing a check mark in the proper box.

Statements	**Totally agree 1**	**Agree 2**	**Disagree 3**	**Totally disagree 4**
1. Inquiry is important in learning science				
2. Creativity is important in learning science				
3. Science can be combined with Arts				
4. Science can be combined with Philosophy				
5. Science can be combined only with the so called STEM subjects (science, technology, engineering, mathematics).				
6. Science must only be based on scientific evidence				
7. Scientists should not question previous scientific findings				

8. According to your opinion, which are the stages in scientific inquiry that a scientist should follow to reach scientific conclusions?

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9. **Do you think there are any benefits by attending a science course in English? Explain your answer.**

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II. Post-Evaluation Questionnaire

Please state your personal beliefs, by putting a tick in the appropriate box. You may tick only one box for each statement.

a/a	**Statement** **Generally, I believe that the creative approach is** *(1) a very efficient practice* *(2) an efficient practice* *(3) a little efficient practice* *(4) no efficient practice* *(5) I don't know* ***Regarding:***	**1**	**2**	**3**	**4**	**5**
	Learning Physics					
1.	Inquiry of scientific concepts					
2.	Communication of scientific concepts					
3.	Making arguments based on evidence					
	The teaching process					
4.	Lesson planning					
5.	Activities					
6.	Use of ICT					
7.	Collaboration					
8.	Creativity					
	Learning English as a foreign language					
9.	Reading					

10.	Listening					
11.	Speaking					
12	Writing					

13.	Please, state any other comments/recommendations you may have regarding the implemented activities.

8. Possible Extension

The key idea that is highlighted in the 'Inquiring the Ghost Particle' demonstrator is its main aim to facilitate and enhance students' inquiry skills. It aims to challenge and capacitate students to explore in an autonomous way current scientific issues and scientific research, beyond the school curriculum; according to their interests. This way, students will gain an intrinsic interest in physics and be enabled to face possible misconceptions they may have. Therefore, the topic for negotiation may differ and change according to current scientific breakthroughs and students' personal interests and queries.

Furthermore, the demonstrator has been realized as a small scale local activity. By encouraging teachers and students from other regions of the country or even from different countries to participate and collaborate in the inquiry of the same scientific issues, it could become a large scale international activity, where students from different countries communicate, exchange information, share their creative ideas and their own scientific understandings. In this case, it is highly recommended the use of the 'Open Discovery Space portal' (http://www.opendiscoveryspace.eu/community/greek-student-parliament-science-834221 as a collaboration area.

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D3.2.31. Engineering a bridge

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1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science - Technology - Engineering - Art - Mathematics

1.2 Type of Activity

Educational activities based on Creativity- enriched Inquiry Based Approaches (school based)

1.3 Duration

2 months

1.4 Setting (formal / informal learning)

Formal learning -the demonstrator involves classroom inquiry activities

1.5 Effective Learning Environment

- Arts-based
- Dialogic Space / argumentation
- Experimentation/Modelisation

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2. Rational of the Activity / Educational Approach

2.1 Challenge

Although our expanding society strongly depends on engineering to shape and build new transport 'paths' to connect people and facilitate transport is not formally included in our primary education curriculum –only addressed through individual projects (Lachapelle and Cunningham, 2007). And yet, that sounds strange since young children from a really early age, even before attending infant school they demonstrate a tendency and show great fascination in taking things apart, disassembling and assembling them, driven by an inner curiosity to figure out how things work.

It is essential to increase engineering literacy among young children if we want to help them understand the human-made world in which we live as well as the effort and knowledge necessary in order to successfully accomplish big building structures. In addition, engineering is closely linked to maths and especially geometry and physics and by making interconnections between these school subjects children could easily distinguish the practical application of those sciences in our everyday life.

2.2 Added Value

Increasing engineering literacy in primary students' is essential in order to support them in understanding the human-made world in which they live not only in terms of building structures but also in considering the social implications that such buildings have on peoples' lives; a key element that would surely enhance their linking with science and society in a personal context. The rationale of the demonstrator applies the Challenge-based learning approach where students deal with a challenge/ topic of global significance, and thus are highly motivated in their research since it derives from and leads to real-world matters (Smyrnaiou, et al., 2015).

The 'Engineering a bridge' demonstrator applies the Inquiry Based Science Learning (IBSE) approach as an effective educational framework that aspires to engage students in an authentic scientific discovery process. Students' engagement with the main principles of engineering is grounded on the process of scientific reasoning and construction of scientific knowledge based on the ground premises of mental exploration, testing hypotheses, data collection and consequent discursive exploration and analysis. In addition, students are encouraged to engage in group discussions in order to communicate their scientific findings/ideas. Argumentation is applied as an efficient educational technique which is found to be tightly related to students' acquisition of scientific knowledge and enhancement in acquiring higher order skills related to problem-solving, scientific reasoning, communication capabilities and analytical thinking (Smyrnaiou, et al. 2015; Sandoval, 2003; Schwarz, et al., 2003).

In addition, a key element of this demonstrator is students' creative manipulation of the acquired knowledge. Students' hands-on engagement with drawings and development of their own bridge models based on the underlying principles of engineering, projects their perception and understanding of the newly acquired scientific concepts (Smyrnaiou & Weil-Barais, 2005). The creative manipulation of engineering concepts enhances students' deep reflection of the relevant principles/theories and engages young learners in their creative and alternative manipulation.

Following the above mentioned learning approaches and activities students manage to fulfill the cycle that encompasses the basic principles of engineering: «inquiry», «imagine», «draw», «create», «improve» and this way they are supported and enhanced in behaving and thinking as engineers.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the 'Engineering a bridge' demonstrator is to **improve pupils' enjoyment of and attainment in engineering via inquiry-based investigations**. The demonstrator's objective is to introduce students to the basic principles and core concepts in the field of engineering and also to enable them to make interconnections between sciences and appreciate their practical application on our everyday life. This way, young learners will be able to understand the human-made world around them and reflect on the necessity of science to make our life easier. In addition, at its core, the purpose of the demonstrator is to enhance students' development of inquiry skills by engaging them in reflective processes while they are dealing with the construction of a bridge.

The 'Engineering a bridge' demonstrator's domain specific objectives are to support students' in:

- Understanding the various fields of engineering and how they affect our world and what engineers do
- Realizing the Inquiry process of scientific concepts and that engineering problems have multiple solutions
- Identifying how geometry affects bridge design and function and applying that knowledge to the design and construction of a bridge.
- Applying science and mathematics to engineering problems
- Using creativity and careful thinking to solve problems
- Understanding the central role of materials and their properties in engineering solutions
- Realizing how society influences and is influenced by engineering

3.2 General skills objectives

In the context of the 'Engineering a bridge' demonstrator, the general skills objectives addressed are:

- Developing creative and critical skills by engaging students in the engineering design process
- Developing collaborative skills
- Understanding and engaging in hands- on activities where there is Science and Art interaction
- Developing a spirit of cooperation and teamwork
- Envisioning one's own abilities as an engineer
- Developing competences of critical / analytical thinking

- Acquiring abilities necessary to do scientific inquiry
- Recognizing, analyzing and imagining alternative explanations and models
- Developing lifelong learning skills
- Developing attitudes befitting a scientific ethos
- Linking with science and society in a personal context

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main goal of the specific demonstrator is to incorporate a series of activities following the basic principles of engineering «inquiry», «imagine», «draw», «create», «improve» in order to engage primary students in an authentic scientific discovery process while dealing with the topic of bridges. This teaching and learning cycle enhances students in applying inquiry, creative approaches and develop competences and skills such as problem solving and critical thinking. Moreover, to address the set challenges students will have to test alternative solutions and engage in experimentation and most of all they will have to communicate, explain and account for their creations as well as test and evaluate them. Their engagement in the challenges will not be based on a true/false assessment but it will require constant application of concrete knowledge deriving from maths, geometry, etc. and their continuous reflection on relevant decisions.

The demonstrator's main aim is to give the opportunity to primary school students to learn about basic principles of engineering and enable them to realize the importance of engineering and the relevant interconnecting sciences in our life. The key principles of engineering will be presented to students through challenging and inquiry–based learning activities, such as creative experimentations, artifacts and drawings, aiming to raise students' interest in the process of identifying how geometry affects engineering designs and function and strengthen their inquiry skills in pursuing knowledge in an autonomous way beyond the school curriculum.

The 'Engineering a bridge' demonstrator has been applied to Arsakeio Primary School of Patra (private school), and specifically to 4th grade students, between 9 and 10 years old. The demonstrator was realized within 2 months-a one hour extra-curriculum lesson each week- and resulted with students' artistic exhibition of their own designs/models.

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4.2 Student needs addressed

It is vital to increase children's engineering literacy and support them in understanding the human-made world in which they live. Considering the fact that young children are are born engineers, engaged from an early age in designing and building activities not only using building blocks but whatever comes into their hands it is quite a shame that education fails to feed their inherent curiosity or even exploit it to help them further their skills. The 'Engineering a bridge' demonstrator also aims to enable students to realize the strong connection between engineering and other sciences, such as maths, art, science. Moreover, it also highlights the strong influence between engineering and society and help students reflect on the importance of sciences for our everyday life. Therefore, in this demonstrator students are engaged in authentic activities-the building of a bridge-and are required to apply critical thinking and creative skills to accomplish their challenge. This way, students become motivated by real life situations and thus become key players of the learning process. Students are highly engaged in applying creative solutions while dealing with topics which are critical for their own lives and surface the essential relevance and connection between the curriculum and their everyday life or future career (Johnson, et al., 2009). In this highly motivating and challenging process, students are guided by inquiry–based approaches to address the problem under negotiation. They develop research questions, identify, investigate and experiment on various alternative solutions and sources for the building of their own design.

5. Learning Activities & Effective Learning Environments

Science topic: Science, Technology, Engineering, Art, Maths (Relevance to national curriculum) Extension to Greek Primary School Maths curriculum Class information Year Group: 4th grade Age range: 9-10 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) toolkit for building a bridge, PC labs, materials for creative construction *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The activities will take place in the classroom *Health and Safety implications? None* *Technology?* Computer and internet access *Teacher support?* Scaffolding
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Weeks 1-2: Brainstorming and Inquiry phase: Discuss and find information about literary and historical aspects that address the topic of bridges. They reflect on their societal implications and their necessity in our lives. They are also engaged creatively in the design of a collage.

Weeks 3-4: Hands-on experimentation phase: Students experiment while building their own model bridges. In this phase, testing is an important issue. Students after building their own model bridges they have to record the type of bridge, maximum weight that each bridge can hold, elements of the bridge, their strengths and weaknesses. Scientific concepts come to the surface and have to be applied since students have to consider that when engineers design a bridge, they must consider how the bridge will be used, how long and wide it should be, and how much weight it has to hold.

Weeks 5-6: Students' communication / argumentation phase: In this phase, students communicate and exchange ideas grounded on reasoning about their model bridges. This way, they develop critical skills and acquire a deeper understanding of the topic under negotiation.

Weeks 7-8: Students' artistic implementation of basic principes of engineering: Through the activities described above students will be encouraged to engage in creative design and building of model constructions. Their final works are exhibited in the school main hall.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Students' deliverables and pre-test, post-test evaluation	*How can the activities be adapted to the needs of individual pupils?* **The 'Engineering a bridge' approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realization. The selection of the topic and the exploration of relevant issues depends on students themselves. During the inquiry phase all students will**	**Science terminology: Beam bridges, Truss bridges, Arch bridges and Suspension bridges.** **Arts terminology: model, materials**

	participate and contribute with relevant to their interest data.	

Session Objectives:

During this scenario, students will be introduced to the basic principles of engineering, using their creativity and imagination.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Build interest in scientific issues and their explanations/social impact. Get engaged with open-ended inquiries related to their lives. Use the web to explore the selected topic/issue	The teacher tries to attract students' attention by eliciting students' relevant questions or highlight the importance of the issue under negotiation. -He/she shows photos of	

		Literary relation of bridges	different kind of bridges. -Raises questions on the adequate type of bridge for each case. (eg what type of bridge would we build if we wanted cars to have access but also be suitable for ships below?)	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students try to identify different types of bridges and the various materials used for their building. They argue on their differences	The teacher identifies possible misconceptions.	Create a collage of bridges

		and the different purposes they served.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students engage in analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modeling, etc.).	Acts as a facilitator of the process (eg. Show students various bridges. What do they all have in common? What are some differences? Which bridge is the strongest?. Which shape is the strongest/ weakest? Why might you use each type of shape to build a bridge?	

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.	Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions. (eg. How does geometry help engineers build bridges?What do we need to build a successful bridge?)	Provide creative examples/models/drawings to strengthen their explanations.
Phase 5:	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of	Students engage in hands-on experimentation. They create their own model	Allows room and enhances	

CONNECT: students connect explanations to scientific knowledge	their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	bridges and test their hypotheses and previous explanations Creativity in identifying connectivism and providing possible solutions.	connectivism with other disciplines	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	They engage in creating artistic model constructions that project their conceptual understanding of the scientific concepts.	Acts as a facilitator of the process. Assess pupil's acquired knowledge.	Artistic projection of scientific concepts through creative modeling.

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflect on the way engineering influences society and vice versa. Elaborate on other scientific issues of current interest that they would like to explore.	Acts as a facilitator of the process.	

6. Additional Information

The resources and lesson plan followed according to the the Inquiry Based Science Learning (IBSE) approach:

- **Historical and literary approach**
  Students are required to search:- for traditional myths/songs, poems that refer to bridges
  -for the very early age of human history for the construction of bridges and reflect on their necessity
- **Search/selection of photos to create a collage**
  Students search and select photos of bridges they find impressive and provide reasons for their choice (artistic view of engineering)

- **Main types of bridges to serve human needs**
  Main topic negotiated: When engineers design a bridge, they must consider how the bridge will be used, how long and wide it should be, and how much weight it has to hold. There are four main types of bridges: a) Beam bridges, b)Truss bridges, c) Arch bridges and d) Suspension bridges.
- **Importance to humanity**
  Students reflect and engage in argumentation approach on the importance of engineering constructions to humanity and the purpose they serve.
- **Exemplary case of the "Harilaou Trikoupi Bridge" in Rio-Antirio**
  The specific bridge was selected since it is located in our hometown.
- **Experimentation/Modeling their own bridges and testing**
  Students after building their own model bridges they have to record the type of bridge, maximum weight that each bridge can hold, elements of the bridge and other details about their models.
- **Assessment phase (worksheets-pre-test/post-test evaluation)**
- **Creative extension in designing their own constructions**

- **Final exhibition of creative artefacts at the school's Main Hall**

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7. Assessment

Both quantitative and qualitative data are required to assess students' cognitive and creative development through the implementation of the Demonstrator. For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)'13 (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016).

In the context of the 'Engineering a bridge' demonstrator, the students' qualitative assessment process was evaluated through worksheets (pre-test/post-test evaluation), collaborative design of model bridges and creative constructions.

[13] 2011 Shawn M. Glynn, University of Georgia, USA http://www.coe.uga.edu/smq/

8. Possible Extension

The key idea that is highlighted in the 'Engineering a bridge' demonstrator is its main aim to support student in understanding the human-made world in which they live and realise the importance of engineering and relevant sciences. Students are introduced to basic principles of engineering through the exemplary case of the bridge. They explore the topic under negotiation in an autonomous way and are given the opportunity to become engineers themselves by applying their own creative ideas. Of course, the topic of negotiation may differ according to students' personal interests or by considering constructions they are familiar with both locally or internationally.

Furthermore, the demonstrator has been realized as a small scale activity, individually by a school. By encouraging teachers and students from other regions of the country or even from different countries to participate and collaborate in the inquiry of the same scientific issues, it could become a large scale international activity, where students from different countries could communicate, exchange information, share their creative ideas and their own scientific understandings. In this case, it is highly recommended the use of the 'Open Discovery Space portal'.

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D3.2.32. Creative colors of climate change: Cool colors sign the dangers & Warm colors suggest solutions

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Argyri Panagiota, Arnaouti Eirini, Zacharoula Smyrnaiou, Menelaos Sotiriou, Eleni Georgakopoulou (NKUA)
Code:	D3.2.32	**Contributors:**	
Version & Date:	V0.1, 2/5/2018	**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.2 Subject Domain

Science, Technology, Engineering, Mathematics

1.3 Type of Activity

- Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).
- Educational Activities that promote school- research center collaboration.

The activity is characterized by an interdisciplinary and exploratory approach to the cognitive subjects of STEM. Activity can be characterized as a large-scale activity at local and European level. It can also be implemented within two or more schools at a national or European level.

1.4 Duration

3 – 4 months

1.5 Setting (formal / informal learning)

The setting of this demonstrator is both formal and informal. The scenario includes IBSL activities, lectures with scientists and researchers, educational visits to Science Museums and department of Universities. Therefore this demonstrator promotes the cooperation between school classes, local communities and research centers.

1.6 Effective Learning Environment

- Communities of practice:
  - Portal: Open Discovery Space portal http://portal.opendiscoveryspace.eu/node/839383,
  - http://tools.inspiringscience.eu/delivery/view/index.html?id=07b8d5ecebaa4342abc8c3a6216680c0&t=p,
  - http://portal.opendiscoveryspace.eu/edu-object/climate-change-839567
  - http://tools.inspiringscience.eu/delivery/view/index.html?id=2cbe9f6329c84d23a1cb19c2999e2f3c&t=p
- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Visits to research centers (virtual/physical)
- Communication of scientific ideas to audience

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2. Rational of the Activity / Educational Approach

2.1 Challenge

While the number of science and technology graduates continues to decline, recent reports estimate the need for a high number of scientists and researchers in Europe (European Union, 2015). A plethora of sources has provided evidence that European industries are having difficulty finding skilled workers, causing the so-called **"STEM skills gap**". Youth education should equip them with the capabilities and skills to adapt and respond to the changes of today's world, characterized by new levels of complexity and contradiction.

The interdisciplinary linking and application of the cognitive subjects of the curriculum to the real world is a challenge for the preparation of the new generation of scientific researchers (Argyri, Lalazi, 2014). **A main problem of Greek educational problem is the strong and sometimes one-side specialization to one cognitive area or a subject.** This may be positive, as students acquire a high level of knowledge, but at the same time this could prevent students from acquiring other skills, such as cooperation, their critical thinking and a global perception to social problems and from finding new interests.

Technology is an integral part of their teaching and learning, supporting the dynamic forms of representations for linking concepts to science lessons (diSessa, 2007; Heid & Blume, 2008; Kaput, Hegedus, & Lesh, 2007). The design of tools for teaching using new communication and information technologies (ICTs) contributes to the modification of the contexts of "teaching and learning " (Vosniadou et al., 1994). Indeed, while seeking to exploit the functionalities of the ICTs (diversification of information sources - written, visual and sound, multiplicities of representation forms, access to libraries and databases, possibility of creating discussion forums, of consulting experts, etc), the educational software produce tools which imply other forms of work and other modes of regulation of the activities of learning (Smyrnaiou, Weil-Barais, 2003).

Despite these prerequisites, **technology does not be used** from the majority of teachers on Greek teaching practice. Although there are educational programs for professional development teaching the use of ICT, there is still an embarrassment using technologies at schools. Moreover, there is an influx of a number of open educational software in education that demand creative construction and manipulative interference rather than usage of pre-manufactured products (Smyrnaiou, Petropoulou, Margoudi, & Kostikas, 2016).

Fragmentation of matter in mathematics gives students the impression that mathematics is not related to the real world, resulting in negative attitudes and perceptions. We propose through cross-curricular activities to encourage students to recognize the connection of mathematics to their daily lives.

The active action of students activates their motivation and develops the cognitive and social skills necessary for self-defined learning and creative management of problematic situations (Wurdinger, 2005).

2.3 Added Value

With this demonstrator students are invited to take up the role of a scientist and study climate change based on the scientific knowledge they have been assigned to. Their research includes the collection of scientific data and elements that capture the changes in the environment, modeling the causes of the phenomenon, exploring through simulations, and analyzing the graphs of the phenomena associated with the variables. The cultivation of scientific skills and critical thinking is accompanied by cooperation among the members of the group (Lalazis, Argyri, 2013), as they discuss the results, to come to conclusions and together as responsible citizens of society, take initiatives and propose solutions for the protection of the planet

Whilst the use of ICT has penetrated the teaching process and research-based learning, we need to create and implement STEM courses that promote the cultivation of methodological skills and competences, experimental research, teamwork and communication between students through cooperative activities. As a result, through this approach we can try to develop a different way of teaching in which students will be empowered by research and collaborative skills and they will be able to design their own knowledge.

3. Learning Objectives

3.1 Domain specific objectives

- The development of innovative ways of connecting the school to modern social reality.
- Participation of students and teachers in the promotion and implementation of research and innovation in the sustainable interaction between science and society.
- Building an effective collaboration between science and society to link student excellence to social consciousness and accountability.
- The development of issues related to research and innovation, where science and technology can play a key role

3.2 General Skills Objectives

In the context of the scenario, the general skill targets under consideration are:

- Active participation in the negotiation of scientific concepts
- Development of creative and critical skills
- Understanding scientific concepts and phenomena
- Developing a spirit of collaboration and teamwork
- Investigating their scientific knowledge on the phenomenon of climate change.
- The development of critical / analytical thinking skills.
- Participation in the analysis of scientific data
- Combining different subject areas and supporting their results

To achieve these goals, regional objectives are formulated to meet the needs of students:

- Develop the skills needed to carry out scientific research
- develop critical and scientific thinking about scientific research
- recognize and formulate those pairs of questions and concepts that guide the scientific research
- use technology to improve research and understanding of scientific concepts
- develop lifelong learning skills

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

With the 'leveling' of the world economy in the 21st century, Science, Technology, Engineering and Mathematics (STEM) has gained new importance as economic competition has become truly global. STEM training has evolved into a post-discipline, an integrated effort that removes the traditional barriers between these issues and focuses on innovation and the applied process of designing solutions to complex environmental problems using current tools and technologies (Kennedy TJ, Odell M. , R., L., 2014: 246-258). "There is a continuing impetus for the development of STEM curricula that substantially integrate technology into as many curricula as possible" (National Research Council of the United States, 2011).

Climate change is a global environmental problem and is linked to many issues in the science (Argyri, Lalazi, 2014) .In the scenario entitled "The planet at risk!: The climate change is colorful with creativity and optimistic about multidisciplinary solutions. Young Climate Change Scientists explore & decide with creativity & responsibility "is characterized by:

- Learning based on research (IBSL)
- Interdisciplinary approach to STEM courses.

By translating and adapting the STEM acronym to this teaching scenario we try to follow the procedure above:

Science: Students are studying the real problem of climate change.

Technology: Students explore the parameters of climate change variables through the following personalization:

1. http://forecast.uchicago.edu/models.html
2. Use of digital tools to process climatic parameter / variable data related to climate change.
3. Cultivation and development of data processing capabilities through mathematical graphs and algebraic computations
4. Development of approaches and research of environmental problem based on knowledge of the science of cognitive science
5. Investigation of the scientific field of knowledge to examine ways of solving the problem.

Engineering: The design process that children use to solve problems as they act as a scientist. Students make decisions about alternative energy sources.

Mathematics: Students cultivate and develop data processing capabilities through mathematical graphs and algebraic computations. They develop approaches and explore an environmental problem based on the skills of cognitive mathematics. They explore the scientific field of knowledge to look at ways to solve the problem.

4.2 Student needs addressed

Research studies find that the combination of interdisciplinarity and teamwork stimulates pupils' interest and improves both their attitudes and self-esteem as well as their ability to collaborate and, by extension, to learning and maintaining knowledge (Rogoff et al. 1998, Prince 2004: Joyce, Weil and Calhoun 2008). Virtual laboratories can be very useful in teaching science, especially in cases where:

- Experimental activities are fast and do not allow easy observation and safe measurement sizes
- The experimental process is very slow and / or complex and is incompatible with the available teaching time. Experiments involve health and physical integrity risks for students
- Training activities require modeling.

Virtual Labs support IBSL in learning science:

- The rights to science are not imposed in a sudden way, but they result from a smooth observation process, with a much greater chance of clarification, understanding and ultimately acceptance.
- Encourage collaboration and communication between STEM and the student.

5. Learning Activities & Effective Learning Environment

Science topic: Science, Technology, Engineering, Mathematics, Digital Storytelling, Art, Video. (Relevance to national curriculum): Greek Junior and Senior High School Curriculum Class information Year Group: 1st-3rd grade of Junior high school and 1st- 2nd grade of Senior High School Age range: 12-16 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) technology lab, laptop, digital editing tools, *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The activities will take place in the classroom, in the technology lab and research centers. *Health and Safety implications? none* *Technology? computer, internet access, digital tools, specified links and tools, such as graphics* *Teacher support? scaffolding*
Prior pupil knowledge Basic concepts regarding math's terminology, climate terminology	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will take on the role of a scientist (and to link their knowledge to study the causes, consequences and ways of tackling the phenomenon of climate change. The methodological scientific inquiry consists of the following stages: 1) Search for sources (Greek and foreign literature) for the collection of scientific data and information (temperature maps, satellite images and pictures, data tables, temperature, sea, ice, etc.) The use of foreign-language literature contributes to a great extent also to the improvement of their language skills. In addition, the writing of pupils' work in English to disseminate their results to the European educational community opens up horizons of cooperation with European partners and fosters their sense of European citizenship and European culture. 2) Use of digital tools and simulations to process climate-related data / variables related to climate change (on-line interactive computer models). Each student has a crucial and important role 3) The focus of special negotiation is the profession of the Meteorologist. All students process real-time data (mean, correlation) and result in conclusions about how to modulate the climate of a place (https://www.slideshare.net/PanagiotaArgiri/meteorologist) Students develop motivation to expand their knowledge in science, technology, engineering and mathematics, but also aspire to pursue a career in these fields. At the same time, the notion that female sex can not follow a scientific career in positive studies is being overcome. The latter also gives the occasion to study the position of women in the phenomenon of climate change. Students, cultivating creativity skills, are very apt to present the profession they will follow to protect the planet from climate change. But they assess and recognize which scientific skills they need to cultivate to have a successful science career. In this educational scenario success to induce students' motivation for science eliminates students' negative attitudes towards this. Using a basic example of Big Ideas of Science in our lives and digital tools and the context of inquiry based science learning this scenario incorporates innovative strategies such as active learning. Students are encouraged to take their own responsibility for their learning, develop their own meanings and construct their own knowledge of greenhouse effect and climate change. The web learning inquiry environment active and constructive participation of the student in activities that demand efficient and flexible strategies and in addition, they help them understand and think logically in activities which set their own learning goals and help them correct their mistakes.		
Assessment Students' deliverables	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Students link science and real life to any stage of school activity as part of every science course (mathematics, physics, chemistry, biology, geology, meteorology,	**Key Concepts and Terminology** **Science terminology:** **Maths, Geometry, Physics, Climate, Meteorologist,** **Arts terminology:** **drawing, painting, digital stories, comics**

	geography). Students engage in science-based learning: by making observations, by asking scientific questions, by looking at books and other sources of information, by planning surveys, by reviewing what is known in the light of experimental data, using tools to collect, analyze and interpret data, the quote of answers, explanations and forecasts and the communication of the results. Scientific research requires the use of critical and logical thinking and the consideration of alternative explanations by finding answers to questions (NCR 1995). "STEM is an interdisciplinary approach to learning where stringent academic concepts are combined with lessons from the real world. Students apply science, technology, engineering and mathematics to environments connecting the school, the local community, work and the global economy. "(Tsoupros, 2009).	

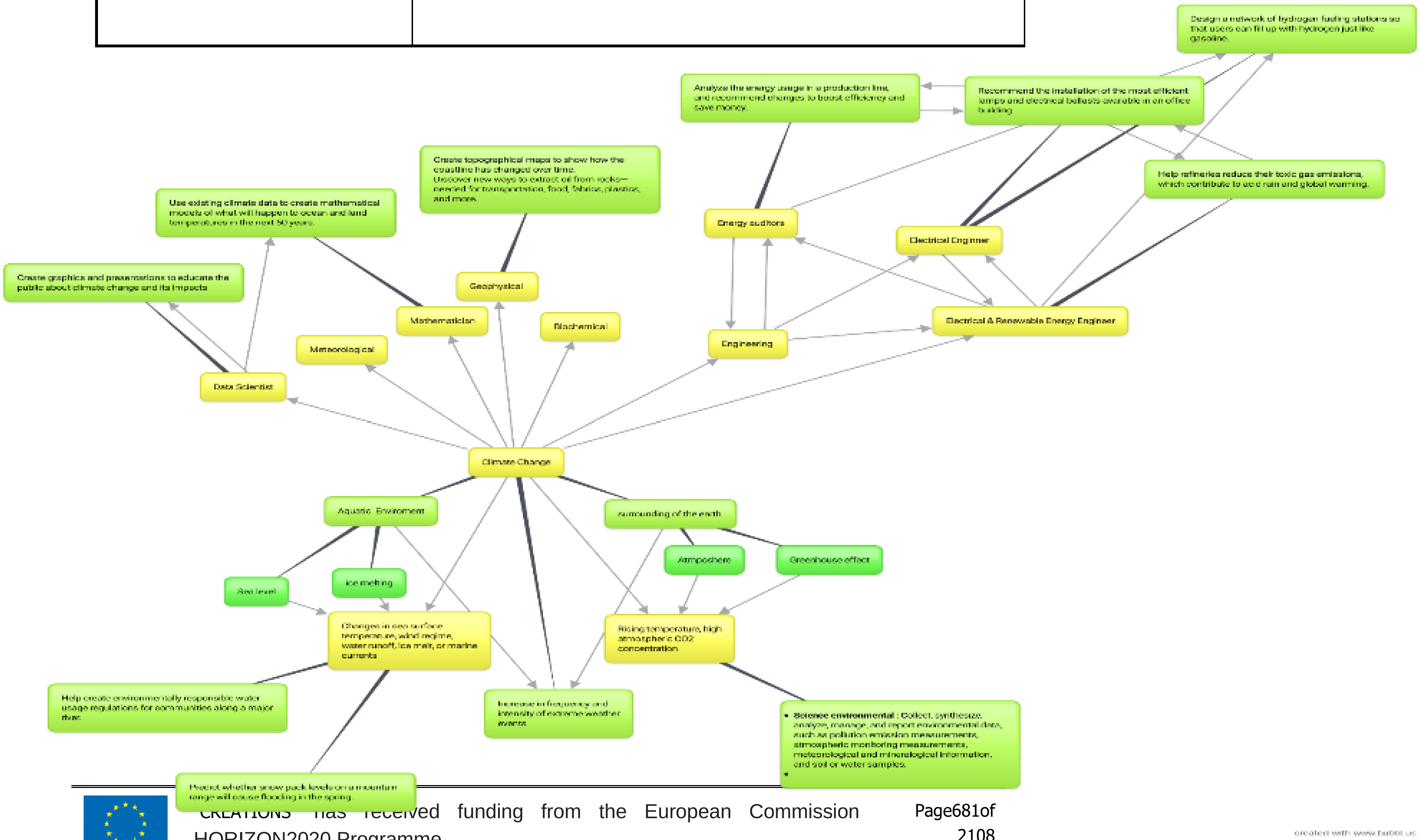
Session Objectives: During this scenario, students will deepen their understanding on scientific concepts and phenomena regarding climate changes and the way of scientific inquiry and face their misconceptions.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge	Students are engaged with teacher's questions. Students are invited to take on the role of a scientist (http://bit.do/concept_map_lesson_plan) depending on their inclinations by thematic field of science and to study the causes, consequences and ways of tackling the phenomenon of climate change.	Teacher will use challenging questions and the web (images, videos) to attract the students' interest in.	

	of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Search for sources (Greek and foreign literature) for the collection of scientific data and information (temperature maps, satellite images and pictures, data tables, temperature, sea, ice, etc.) recording changes to the planet as reflected by the climate change phenomenon (http://bit.do/worksheets_of_students).	The teacher identifies possible misconceptions, he/ she tries to explain any difficulty of maps, satellite images etc. and help to combine the evidence from different sources.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	They use digital tools and simulations to process climate-related data / variables related to climate change (on-line interactive computer models). Through mathematical modeling, they cultivate and develop mathematical data	Act as a facilitator of the process	

		processing and analysis skills, through mathematical graphs and algebraic calculations. (http://bit.do/graphical_representations) Each student has a crucial and important role as the geologist maps the climate change, the chemist studies the effect of carbon dioxide gases, the oceanographer effects the phenomenon at sea level, the natural energy changes in the atmosphere, the mathematical analyzer through modeling attempts to predict impacts in the coming years and the environmental analyst analyzes the consequences. Together they analyze the carbon dioxide emission link with electricity (http://electricitymap.tmrow.co/) and look for alternative energy-saving ways (https://4769.stem.org.uk/Science_Skills/index.html#)		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The focus of special negotiation is the profession of the Meteorologist. All students process real-time data (mean, correlation) and result in conclusions about how to modulate the climate of a place. (https://www.slideshare.net/PanagiotaArgiri/meteorologist)	Act as a facilitator of the process	

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students discuss how a climate change can affect peoples' lives according to their living area, their profession etc. They talk about different ecological problems, they try to convince on which problem affects more our lives and they make arguments on how humanity can protect the environment, by suggesting effective ways. They try to represent their knowledge by drawing pictures of ecological problems.	Make the whole procedure easier and help discussion concluding to some main points.	**Drawing ecological problems, the negatives of climate change etc.**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students also visit National Meteorological Station and they discuss with meteorologists, geologists etc. An online meeting was held with the Aegean Sea Department of Aegean University. Professionals informed students for scientific subjects related to the growing field of mathematical ecology.		

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students develop motivation to expand their knowledge in science, technology, engineering and mathematics, but also aspire to pursue a career in these fields. They talk about different ecological problems, they try to convince on which problem affects more our lives and they make arguments on how humanity can protect the environment, by suggesting effective ways. Students, cultivating creativity skills, are very apt to present the profession they will follow to protect the planet from climate change. But they assess and recognize which scientific skills they need to cultivate to have a successful science career. They decide to take measures to protect the environment and to make people more sensitive to global change. They decide to make posters by using comics and digital tools.	Teacher balances the outcomes of the creative procedure.	**Digital Art, Comics**


Design a network of hydrogen fueling stations so that users can fill up with hydrogen just like gasoline.
Analyze the energy usage in a production line, and recommend changes to boost efficiency and save money.
Recommend the installation of the most efficient lamps and electrical ballasts available in an office building
Create topographical maps to show how the coastline has changed over time.
Uncover new ways to extract oil from rocks—needed for transportation, food, fabrics, plastics, and more.
Use existing climate data to create mathematical models of what will happen to ocean and land temperatures in the next 50 years.
Help refineries reduce their toxic gas emissions, which contribute to acid rain and global warming.
Create graphics and presentations to educate the public about climate change and its impacts
Energy auditors
Electrical Enginner
Geophysical
Mathematician
Biochemical
Meteorological
Engineering
Electrical & Renewable Energy Engineer
Data Scientist
Climate Change
Aquatic Environment
Surrounding of the earth
Atmposhere
Greenhouse effect
Sea level
Ice melting
Changes in sea surface temperature, wind regime, water runoff, ice melt, or marine currents
Rising temperature, high atmospheric CO2 concentration
Help create environmentally responsible water usage regulations for communities along a major river.
Increase in frequency and intensity of extreme weather events
Science environmental : Collect, synthesize, analyze, manage, and report environmental data, such as pollution emission measurements, atmospheric monitoring measurements, meteorological and mineralogical information, and soil or water samples.
Predict whether snow pack levels on a mountain range will cause flooding in the spring
created with www.bubbl.us

6. Additional Information

This interdisciplinary scenario is being implementing in January 2018 through the exploratory learning environment of the European Ispiring Science Education project in student sections of the 1st grade Evangeliki Model High School of Smyrna (simulation, problem-solving, virtual workshop, phenomenon modeling through the linear function).

As Greek schools follow a paternalistic approach by teaching on a monotonous way and confirming a traditional approach for the role of student and educator, Inquiry Based Science Education (IBSE) is in accordance to the objectives of the Curriculum for Mathematics in Compulsory Education which are characterized by the fact that the student should (a) analyze, interpret and intervene in his / her social environment, using mathematics as a tool and (b) analyze and interpret the way in which mathematics for decision making in the social environment (Pedagogical Institute in the context of the implementation of the "NEW SCHOOL, 21st Century School - New Curriculum). Education, learning and teaching is a collaboration inside and outside the school that prepares students to make conscious and substantiated choices about the future of society.

This demonstrator is based on virtual laboratory environments which are a basic digital tool, which many European schools have computer classes, tabs and high-speed Internet connections using a huge variety of web-based learning applications, simulations and visualizations (Dikke et al., 2015). So students can also develop technological skills, which help them to follow global developments.

This scenario can also be used to integrate the "Big Ideas of Science" into the curriculum of science studies and it follows the principles of open schooling.

Under the framework of this scenario it could be organized meetings with researchers and scientists to inform students about the potential of climate change related professions.

For educational community additional links for extensions

http://edcommunity.esri.com/Resources/Collections/earth_geoinquiries

Folder Mapping Climate_1

Folder Mapping Climate_2

https://www.dropbox.com/s/6xbshz7vt4099fv/Mapping_Climate_1.zip?dl=0

https://www.dropbox.com/s/qx7ds5vqrji6go6/Mapping_Climate_2.zip?dl=0

ESA Climate Change

http://www.esa.int/Our_Activities/Space_for_climate/A_global_challenge

https://www.acs.org/content/acs/en/climatescience/about.html

1. What is the evidence that Earth is warming?
2. What is the atmospheric greenhouse effect?
3. What are the properties of greenhouse gases? What are the Earth's greenhouse gases?
4. How are a warming Earth and increased greenhouse gases related?

5. Have human activities contributed to Earth's greenhouse gases? How do we know that human activities increase greenhouse gases?
6. What is the mechanism of the atmospheric greenhouse effect? What is radiative forcing?
7. Where is the Earth's carbon?
8. What are feedbacks in the climate system? What is climate sensitivity?
9. How are oceans affected by the Earth's energy imbalance? How are oceans affected by increasing atmospheric CO2 levels?
10. What role does chemistry play in climate science?
11. What is the ACS position on climate science?

https://www.acs.org/content/acs/en/climatescience/energybalance/earthtemperature.html

https://www.acs.org/content/acs/en/climatescience/atmosphericwarming.html

https://www.acs.org/content/acs/en/climatescience/atmosphericwarming/climatsensitivity.html

https://www.acs.org/content/acs/en/climatescience/greenhousegases.html

https://www.acs.org/content/acs/en/climatescience/oceansicerocks.html

https://www.acs.org/content/acs/en/climatescience/references.html

http://www.realclimate.org/index.php?cat=10

On-line interactive computer models allow you to play with the physics and chemistry behind the global warming forecast.

http://electricitymap.tmrow.co/

Proposals of recourses for educational scenario

http://www.scientix.eu/resources/details?resourceId=9192

http://www.scientix.eu/resources/details?resourceId=4892

http://practicalaction.org/mtl-climate-change

http://www.scientix.eu/resources/details?resourceId=4889

http://www.scientix.eu/resources/details?resourceId=3603

http://www.scientix.eu/resources/details?resourceId=2913

http://www.scientix.eu/resources/details?resourceId=3212

http://www.scientix.eu/resources/details?resourceId=3097

http://www.scientix.eu/resources/details?resourceId=2960

CREATIONS has received funding from the European Commission HORIZON2020 Programme

http://www.scientix.eu/resources/details?resourceId=2961

Space Awareness project

Climate box

1. Exploring the Big Ideas of Science recommendation system in ISE repository environment http://portal.opendiscoveryspace.eu/repository-tool-ideas in order to select the topic of educational scenario that help my students to relate with the examples of our daily lives Big Ideas of Science.

2. Using authoring tool of creation scenario in ISE platform:

Guide for teachers of Inspiring Science Education: Lazoudis A.,Zerbas P., Sampson G., Kolobou L., Tiemann R., Schumm M., Langheinrich. J., Bogner. F., Baldea. M., Kastrinogiannis J.,Sotiriou S., (Editing : Stilianidou F.,) (Athens 2016).

3. Getting experience in problem solving questions :

Zerbas P.; Sampson D.; (2015) Supporting the Assessment of Problem Solving.Competences through Inquiry-based Teaching in School Science Education: The Inspiring Science.

(Available http://www.slideshare.net/Demetrios_Sampson/ise-tools onlineseminaretwinning

4. Assessing Problem-Solving Skills in PISA 2012; Creative Problem Solving: Students' skills in tackling real-life problems In Volume V, OECD 2014 p.29. Bibliography of concepts of inquiry based science learning :

Elster D.;(2012). "Inquire for Students" –How to promote Inquiry Based Learning In International Conference New Prespective in Science, 2nd Edition.

Davis, R.; (1995) Interdisciplinary Courses and Team Teaching, In Phoenix, AZ: American Council on Education and the Oryx Press.

NCR ; National Research Council (1995). National science education standards In Washington, DC: National Academy Press.

http://www.esa.int/ESA, http://www.esa.int/Our_Activities/Space_for_climate/A_global_challenge

http://esamultimedia.esa.int/docs/EarthObservation/ESA_CCI_140605.pdf, support in selection topic of climate change as example of Big Ideas of Science in our lives and as "hottest" topic in today's headlines for protection enviroment of our planet.

Digital tool of ISE repository related with big ideas of scenario and topic of climate change, adding in educational scenario:

http://portal.opendiscoveryspace.eu/content/very-very-simple-climate-model-832897

https://scied.ucar.edu/activity/very-very-simple-climate-model-activity

https://scied.ucar.edu/simple-climate-model

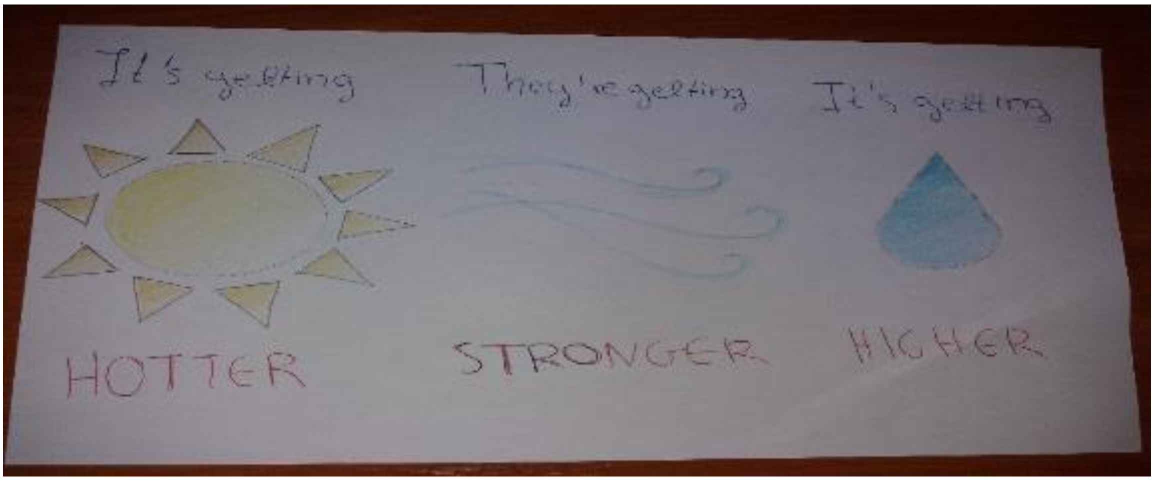
A simple model for climate that used in investigation pase to explore how the rate of carbon dioxide emissions affects the amount of CO2 in the atmosphere and Earth's climate.

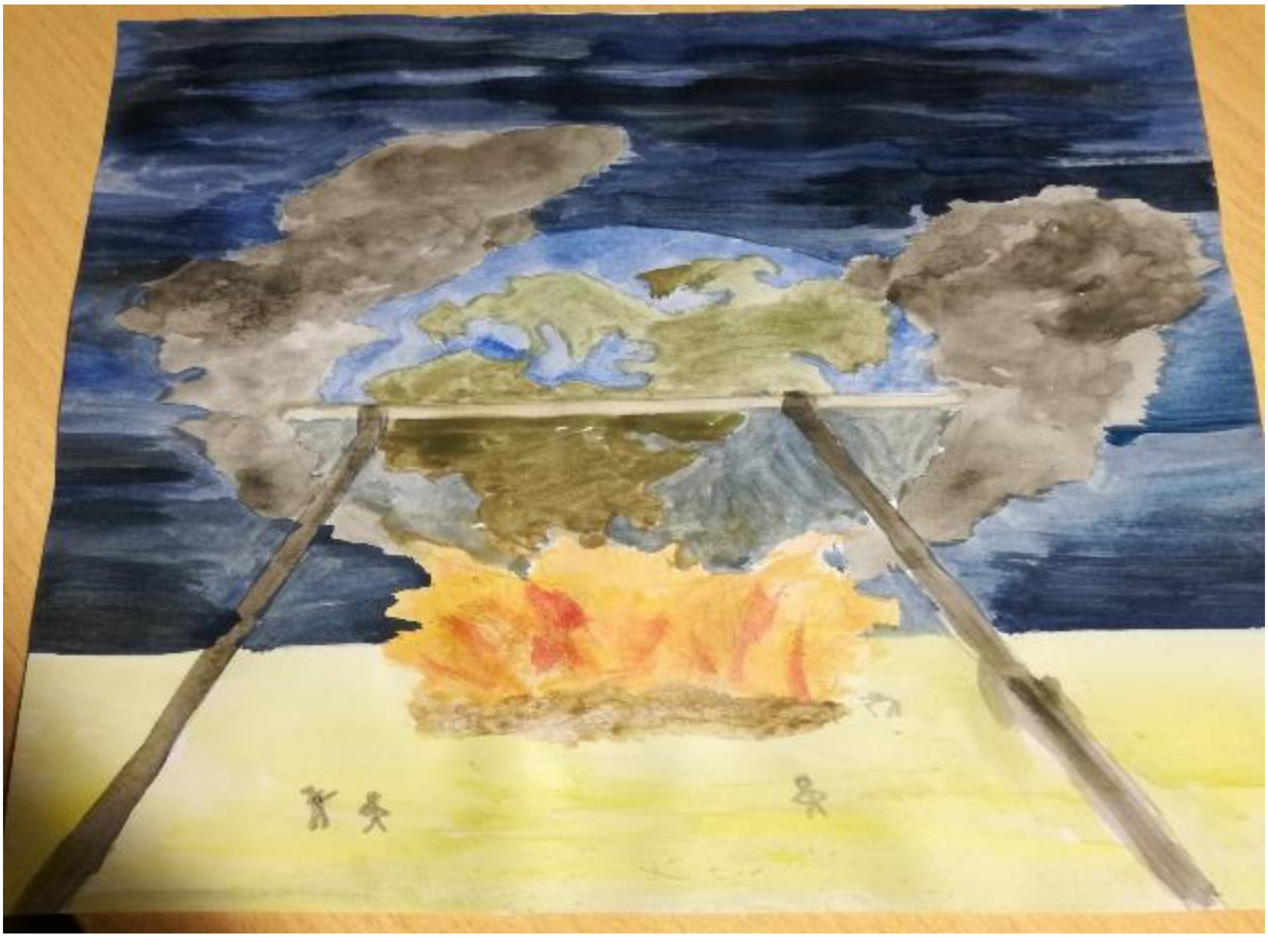
http://portal.opendiscoveryspace.eu/content/enervia-832755

http://www.kineticcity.com/mindgames/enervia/

An similation game that provide learning about sources and energy management in analysis phase of suggestion solutions to protect enviroment of climate change.

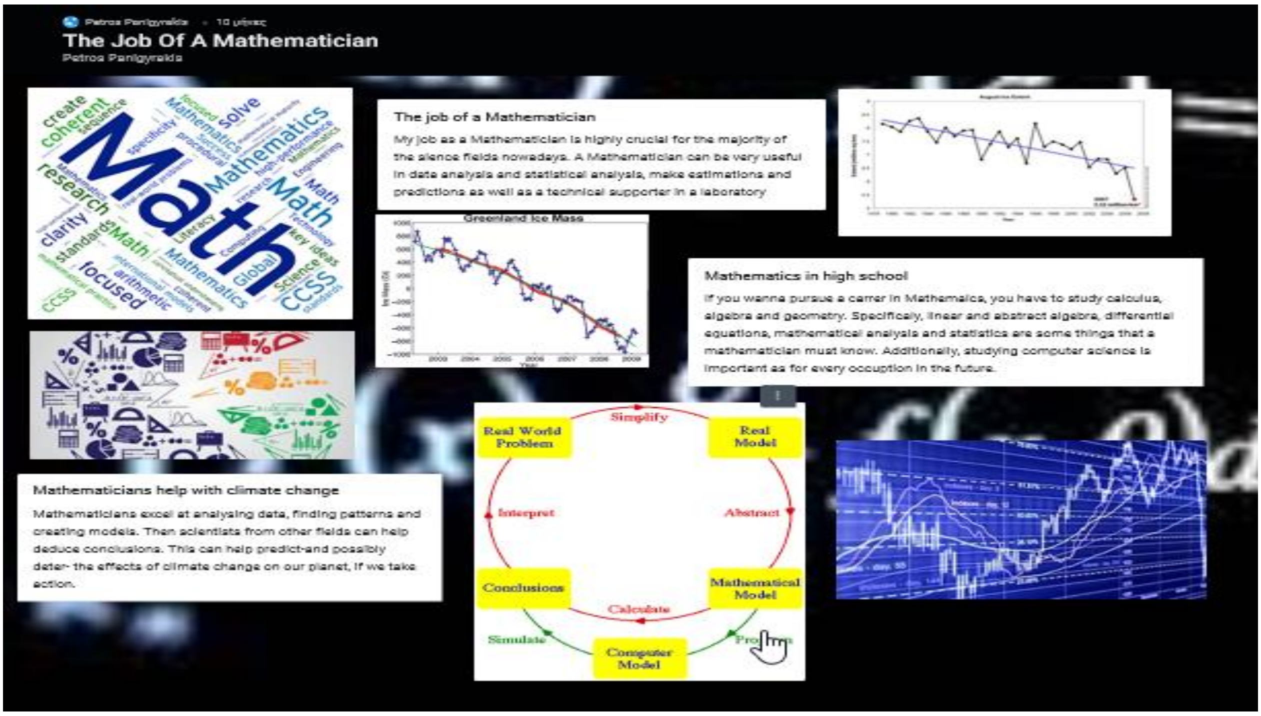
Arts Drawing

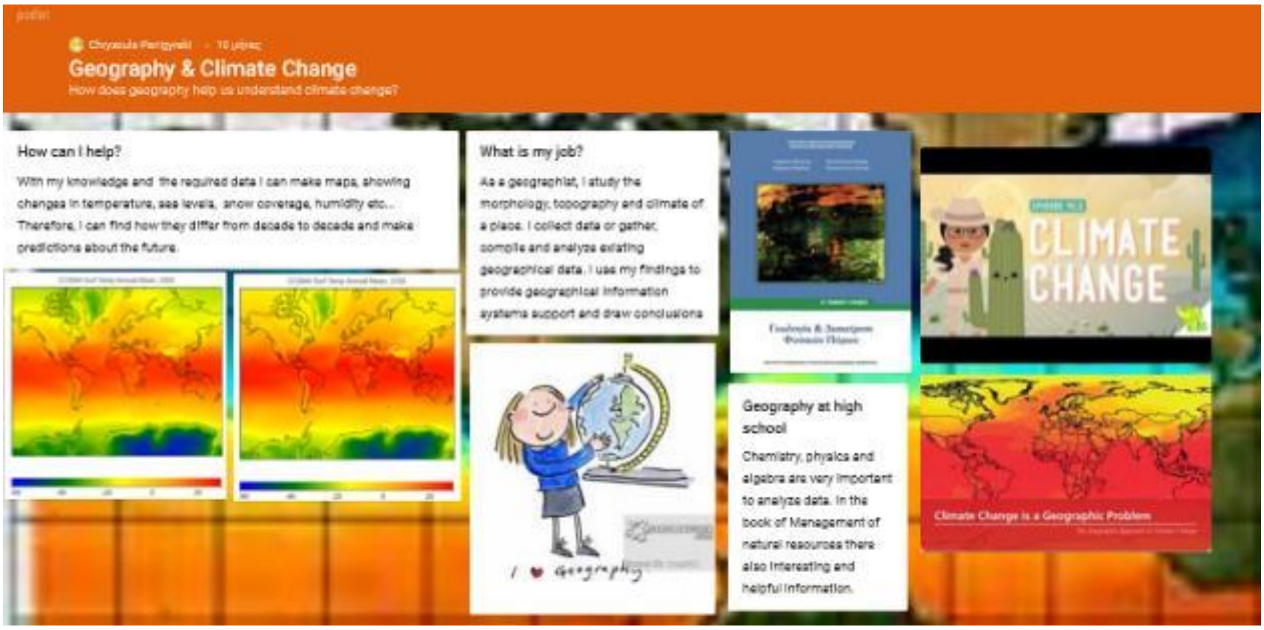


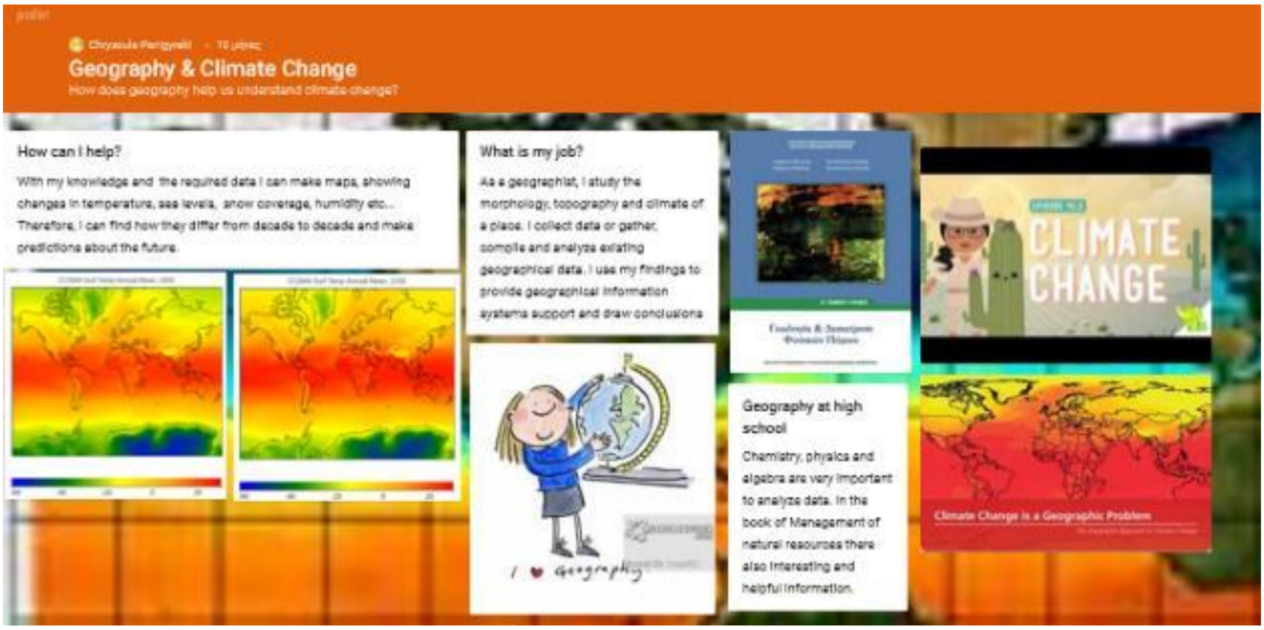


Digital art


What is my job?
Environmentalism is a broad philosophy, ideology, and social movement regarding concerns for environmental protection and improvement of the health of the environment.
1) An environmentalist broadly supports the goals of the environmental movement.
2) is engaged in or believes in the philosophy of environmentalism
3) Also environmentalists are sometimes referred to using informal or derogatory terms such as 'greenie' and 'tree-hugger'.
THE STORY OF
LIFE & THE ENVIRONMENT
An African perspective
General
At its crux, environmentalism is an attempt to balance relations between humans and the various natural systems on which they depend in such a way that all the components are accorded a proper degree of sustainability.
Environmentalism - Wikipedia
'Sooner or later, we will have to recognise that the Earth has rights too, to live without pollution.'
Environment and Climate Change
Conserving natural resources is a basic requirement for sustainable development and improving the quality of human life. To reverse the trend towards resource degradation, we need to give greater priority to ecological principles.
Watch the video here : https://www.giz.de/en/ourservices/environment_and_climate_change.html
How to become an environmentalist
Step 1: Prepare in High School
Step 2: Go to College
Step 3: Consider an Advanced Degree
Step 4: Gain Experience
Step 5: Seek Employment
Climate Change
& Environment


The Job Of A Mathematician
Petros Panigyrakis
The job of a Mathematician
My job as a Mathematician is highly crucial for the majority of the sience fields nowadays. A Mathematician can be very useful in data analysis and statistical analysis, make estimations and predictions as well as a technical supporter in a laboratory
Greenland Ice Mass
Mathematics in high school
If you wanna pursue a carrer in Mathematics, you have to study calculus, algebra and geometry. Specificaly, linear and abstract algebra, differential equations, mathematical analysis and statistics are some things that a mathematician must know. Additionally, studying computer science is important as for every occuption in the future.
Mathematicians help with climate change
Mathematicians excel at analysing data, finding patterns and creating models. Then scientists from other fields can help deduce conclusions. This can help predict-and possibly deter- the effects of climate change on our planet, if we take action.
Real World Problem
Simplify
Real Model
Abstract
Mathematical Model
Calculate
Conclusions
Interpret
Simulate
Computer Model


Geography & Climate Change
How does geography help us understand climate change?
How can I help?
With my knowledge and the required data I can make maps, showing changes in temperature, sea levels, snow coverage, humidity etc... Therefore, I can find how they differ from decade to decade and make predictions about the future.
What is my job?
As a geographist, I study the morphology, topography and climate of a place. I collect data or gather, compile and analyze existing geographical data. I use my findings to provide geographical information systems support and draw conclusions
Geography at high school
Chemistry, physics and algebra are very important to analyze data. In the book of Management of natural resources there also interesting and helpful information.
CLIMATE CHANGE
Climate Change is a Geographic Problem


Geography & Climate Change
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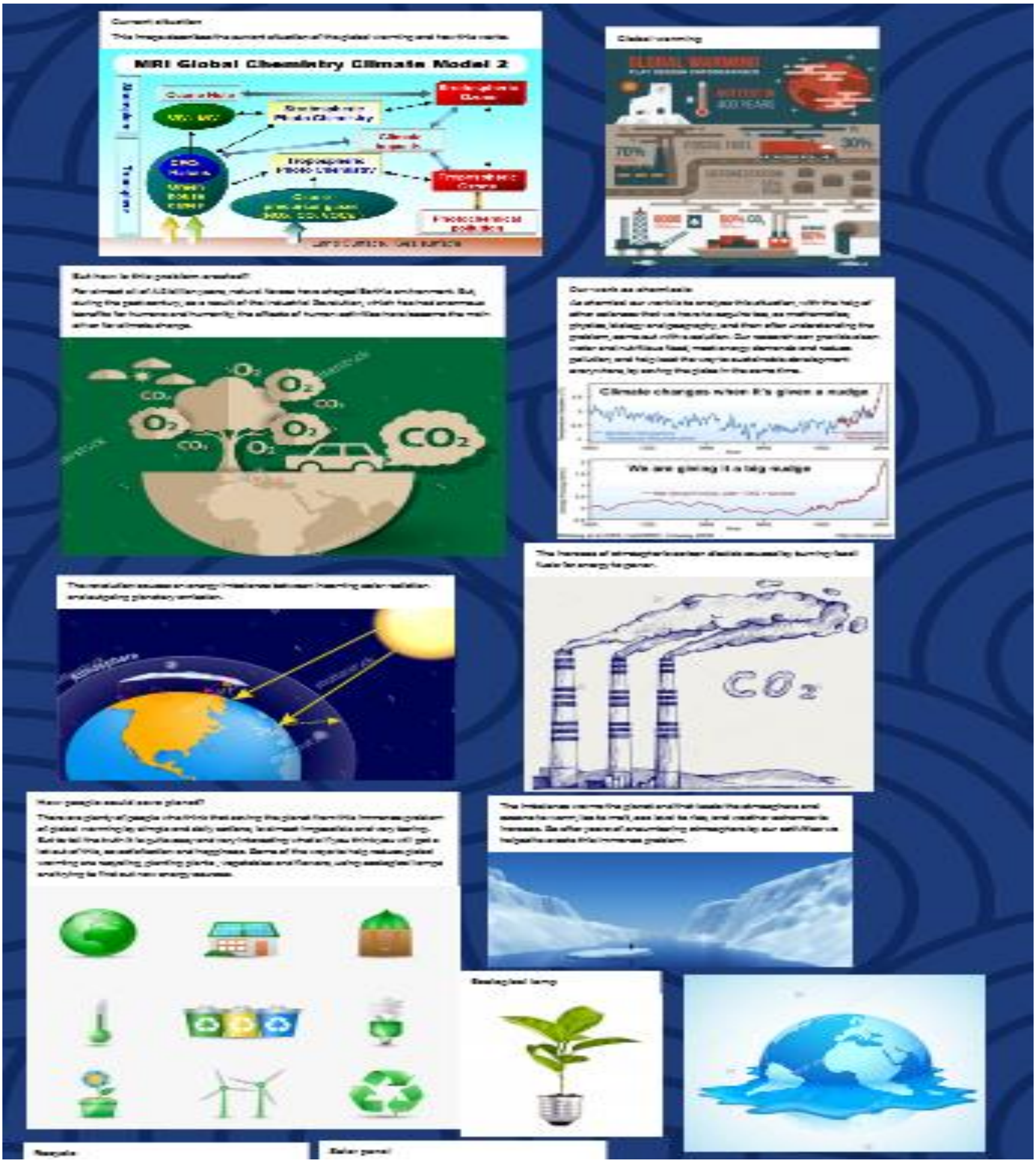
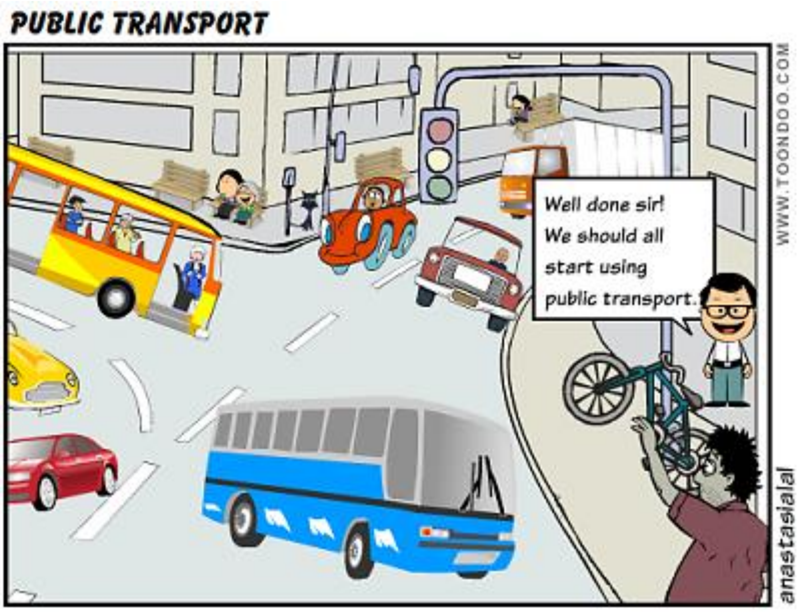
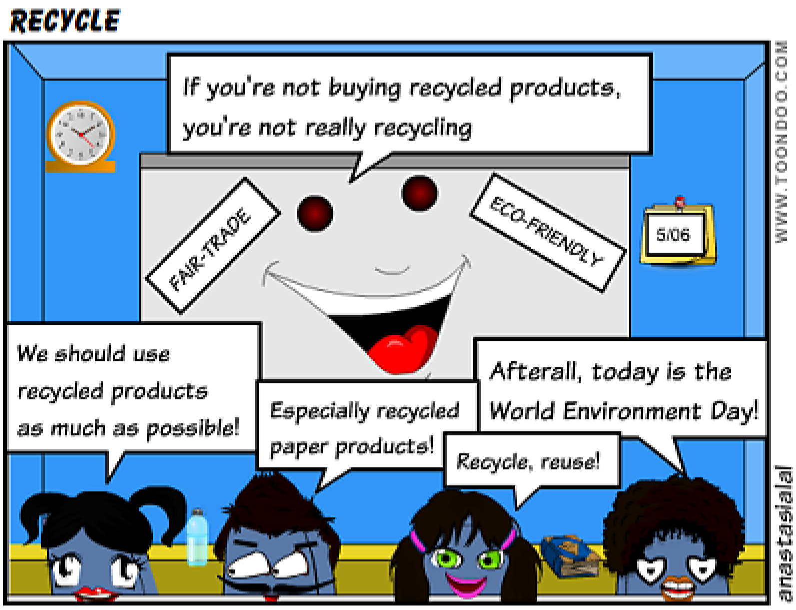

MRI Global Chemistry Climate Model 2
Climate changes when it's given a nudge
We are giving it a big nudge

Comic

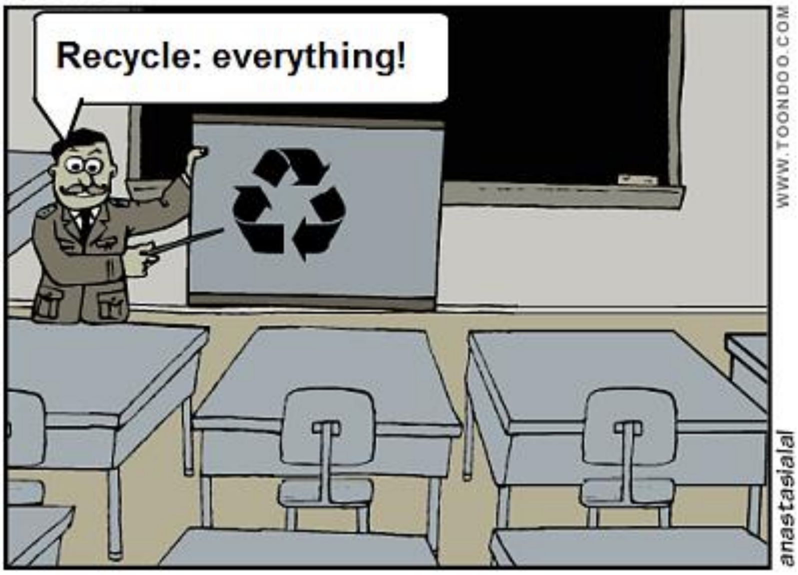


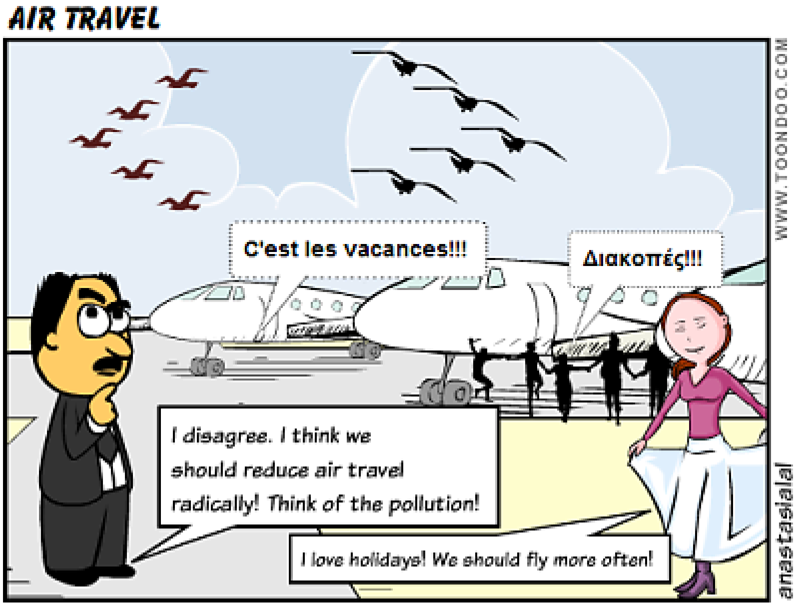


CREATIONS has received funding from the European Commission HORIZON2020 Programme

WATER USE

RECYCLE




AIR TRAVEL
C'est les vacances!!!
Διακοπές!!!
I disagree. I think we should reduce air travel radically! Think of the pollution!
I love holidays! We should fly more often!
WWW.TOONDOO.COM
anastasialal

7. Assessment

For quantitative assessment we recommend the use of the "Science Motivation Questionnaire II (SMQ-II) ' 2 (Glynn, et.al, 2011; maximiliane, Schumm, Bogner, 2016) that is addressed to students.

8. Possible Extension

Through this project students learn about scientific concepts by combining different domain areas, and by realising that a scientist use his/her knowledge to find solutions to everyday problems. By learning more evidence about a field and by cooperating with others we can solve major problems, such as climate danger and make our lives better. The combination of different ways of learning helps students to find their own interests and skills and feel useful. This project can be expanded on a large scale international activity, as each climate problem affects differently according to the place, the professions etc.

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.33. Mathematical Tour on Art Math Stories in Museums -Math Stories in Museums

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Argyri Panagiota Zacharoula Smyrnaiou, Menelaos Sotiriou, Eleni Georgakopoulou (NKUA)**
Code:	D 3.2.33	**Contributors:**
Version & Date:	**V0.1, 2/5/2018**	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematical, STEM, Art with digital tools

1.2 Type of Activity

- Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).
- The activities suggested through this demonstrator are done on a local level, so it is a local activity.

1.3 Duration

One school year

1.4 Setting (formal / informal learning)

The activity is both formal and informal. The main scenario includes IBSL activities on school but especially educational visits to Science Museums. The local community is also involved in a creative way.

1.5 Effective Learning Environment

The Effective Learning Environments according to the framework (D.2.3.) are :

- Experimentation (Science laboratories and eScience applications)
- Dialogic Space / argumentation

2. Rational of the Activity / Educational Approach

2.1 Challenge

In the modern school of the 21st century, where the holistic development and cultivation of the students' personality is sought, study visits are integrated for the contact and the active engagement of students with objects of learning. However, students are not engaged in interdisciplinarity approaches, as they are taught on a monotonous way. Teachers also believe that the right lesson are done inside the classroom following the principles of each subject domain, and they are not willing to find creative ways to motivate their students but also to help them acquire cognitive and communicative skills.

2.2 Added Value

Museums are established institutions, but they also exist in a changing world. How can we find relations between museums and STEM education? What are the dimensions of "museum education" as a discipline of pedagogy and how do innovative approaches in the teaching of modern science apply to museums? Starting from the assumption that material objects within museums are as much a part of the weave of our lives, such a question could be answered. A museum is a living space, a potential extension of the STEM classroom, as students use the knowledge they acquire at school in order to understand the importance of reports and exhibits (Argyri, 2017).

Are there ways of expanding the educational visits to museums with creations in science?

By this ways, we search for connections between science, creativity and museums.

"Material Culture" *defines human interventions and the remains of human activity, from the point of view of the traditional technology and productive history of a place*. The planning of educational activities with cultural material of the museums through the connection with the curriculum agrees with the views of Modern Museology, Material Culture Theory and Modern Theories of Learning Mathematics (P. Vergo, 1989; E. Hooper-Greenhill, 2000; T. Bennett, 1995; SM Pearce, 1994; U. Eco, 1993 cited in Argyri, 2017).

The thematic areas of the Museums can be a basic tool for the realization of out-of-school activities that untie pupils from the classroom and give them incentives for self-action and active participation (Argyri, 2017).

The design and implementation of modern, open alternative methods and objectives, which are suitable for approaching and exploiting the cultural material of museum spaces, indirectly also provide the possibility of enriching, renewing and redefining school education methods. Thus, the design and systematic implementation of modern museum-based educational programs based on the subject can also act as a challenge for school education, which is distinguished by its traditional orientation, in relation to which, among others, greater importance is attributed to curriculum than in the learning process (Nakou E., 2006 cited in Argyri,P., 2017).

Moreover media can be used in almost any discipline to enhance learning, both in class, and also for out-of-class assignments. Short film and television clips, written articles, and blog postings can be viewed to reinforce concepts and spark discussion. Songs and music videos, especially when lyrics are made available, can be used to the same effect. Movies provide an excellent vehicle for educational purposes (Argyri, et al. 2016). This mean that we could encourage students create digital creations based on materials of museums.

3. Learning Objectives

3.1 Domain specific objectives

The inclusion of cross-curricular and experiential approaches through the exhibitions in the thematic field of cultural material and according to the subject matter of each Museum, can ***be a useful tool for the mobilization and the cultivation of interest of pupils for learning science.*** (Argyri, P. et.al, 2017)

- To develop a positive attitude towards science.
- Connection among history, architecture and mathematics
- Learning about the history through the exhibits of Museums. Pupils became acquainted with various periods of history and came into direct contact with certain of its sources.
- Cultivate skills of making scripts for movies
- Promoting ICT tools by using digital skills for making videos and animations
- Collaborating on activities with art designs in geometry and presentations

3.2 General skills objectives

In the context of the Science Stories in Museums, students' general skills objectives are:

- The cultivation of the search spirit,
- the promotion of inclinations,
- the strengthening of interests,
- the learning of ways of organizing strategies and methods for solving problematic situations,
- the ability to select and synthesize material
- the development of cooperativity and the fruitful and fruitful dialogue among students

Within this connection framework, the basic principles of the educational Programs, which seek **to develop mathematical literacy,** the ability of the individual to analyze, interpret and intervene in his social environment and in the world around him, using mathematics as a tool to understand how mathematics is used to make decisions in the social environment. (Pedagogical Institute, Guide for Teacher, 2015 cited in Argyri, 2017, Argyri, 2016 ;).

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The inclusion of experiential actions and approaches in the field of museum culture material opens the windows connecting mathematical knowledge to the real world. This explains the importance and role of mathematical knowledge in the development and shaping of social structures, and the student understands that "mathematical concepts, structures, and ideas have been invented as tools to organize the phenomena of physical, spiritual world ".

Within this connection framework, the basic principles of the Mathematical Studies Programs, which seek to develop mathematical literacy, relate to the ability of the individual to analyze, interpret and intervene in his social environment and the world around him, using mathematics as a tool and understanding how mathematics is used to make decisions in the social environment.

Below this requirement worksheet activities include:

-Exolution of problems aiming at the cultivation of mathematical reasoning, analytical, synthesis and critical thinking, supplemented by the formulation of arguments, judgments, criticism and conclusions.

-Statistics diagrams and tables, aimed at enabling students to be able to understand and critically evaluate the results presented, the interpretations and the conclusions drawn from various statistical studies.

-Development of geometric concepts and application of computational methods on the objects of cultural material of each Museum, aiming at cultivating and practicing flexibility in the way of geometric thinking of students, which will be used as a tool for the study and justification of properties of geometric shapes.

Depending on the thematic area of each Museum, one or two or three of the above directions are selected or, sometimes, for the examination of specific topics, additional activities are proposed in the context of the exploratory and analytical approach of cultural material. (Argyri, 2017)

4.2 Student needs addressed

The principles of learning and teaching assume exist, on the condition that:

a) Learning requires active and constructive participation of the student in activities that demand efficient and flexible strategies and in addition, they help them understand and think logically in activities which set their own learning goals and help them correct their mistakes (Argyri, 2014)

b) New knowledge is constructed better when associated with pre-existing knowledge and organized through the effective understanding and not through memorizing.

We rely on the basic pedagogical and didactic principle according to which learning is better when incentives and interest are created in learning and in the context of innovative teaching approaches dictated by the curriculum chosen as the subject matter of the project examining the relationship between mathematics and art.

Students also combine their facts and their data on a personal way, so these activities help students to express their own way of thinking and support their acts with arguments. The co- creation engages them in meaningful activities, in which they will collaborate and negotiate different ways of expressing themselves.

5. Learning Activities & Effective Learning Environments

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Science topic: Geometry, Art (Relevance to national curriculum) Class information Year Group: 1st-3rd grade of Junior High school, 1st- 2nd grade of Senior High school Age range: 12-16 Sex: both Pupil Ability: mixed	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) laptop, digital tools, drawing tools, questionnaire and rubrics *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* *Classroom, technology lab, museum* *Health and Safety implications? none* *Technology? digital tools, computer, internet access* *Teacher support? scaffolding*
Prior pupil knowledge Students need to have some basic knowledge of science knowledge of the curriculum.	

The educational scenario of the Mathematics for the planning of the educational visit consists the following phases: - Worksheet for activities before the educational visit to the Museum. It is the expulsion and mobilization of students' interest in exploring the material world of the Museums that marks and its contact with human interventions and the remains of human activity, from the point of view of the traditional technology and productive history of each place. - Worksheet for activities during the educational visit to the Museum. Students undertake an active investigative role with the aim of linking mathematics to real situations arising from the material culture of the Museums. -Worksheets after the educational visit to the Museum. The completion of the educational visit is backed up and takes appropriate extensions so that students, using their knowledge, experience and information, undertake to handle open mathematical problems and activities related to the thematic units of the respective Museum. -Digital arts and videos based on science knowledge of museums.		
Assessment Students artistic products	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* *These activities are grounded on students' special needs and interests. During the Inquiry Phase students develop scientific thinking but also act according to their skills, needs and interests.*	**Key Concepts and Terminology** **Science terminology: Geometry** **Arts terminology: digital stories**
Session Objectives: During this scenario, students will ɑnewer research questions, make Bibliographical review, use new technologies and properties of mathematics educational software and create artistic creations.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	**Progress and Preparation** Students recall or regain basic science knowledge by their curriculum, methods or algorithmic pathways from their long-term memory to resolve activities before or during the visit.	Teacher uses challenging questions and the web (images, videos) to attract the students' interest before the educational visits.	

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Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	It is the expulsion and mobilization of the students' interest in exploring the material world of the Museums which marks and its contact with the human interventions and the remains of human activity, from the point of view of the traditional technology and productive history of each place	In cases where the teacher considers it necessary, depending on the students' cognitive level, the preparation includes repeating pre-existing mathematical knowledge and methods of the curriculum, which are directly related to the next phase.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Worksheets for the implementation of activities during the educational visit to the Museum. Through exploration and discovery students take an active role in	The teacher follows and watches the whole procedure and identifies possible misconceptions.	

		linking mathematics to real situations that arise during the "meeting" with the material culture of the Museums.	Teacher promotes dialogical procedure and acts as a facilitator of the process.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Worksheets for the implementation of activities after the educational visit to the Museum. The completion of the educational visit is backed up and takes appropriate extensions so that students, by making use of their knowledge, experience and information, undertake to process open mathematical problems and	Teacher promotes dialogical procedure and acts as a facilitator of the process.	

		activities related to the thematic units of the respective Museum.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The continuation of the activities after the museum aims at the assimilation of experiences and information as a single body of cognitive knowledge, which is expanded with generalizations and additional activities aimed at drawing conclusions and making art creations.	Teacher encourages the whole procedure.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Educational visits to museums. Especially the Acropolis of Athens and its monuments are universal symbols of	Teacher helps students to make stronger connections	

		the classical spirit and civilization. Except for the fact that the Acropolis is the greatest architectural and artistic complex bequeathed by Greek Antiquity to the world includes many mathematical and geometrical concepts. In addition, materials of the Acropolis museum are formed my mathematics. **For connecting the educational visits** about history with art ,we prepared activities of making scenarios, videos and animation based on historical material collected from the Acropolis site and museum.	between science and real world	

		These activities were planned to be created in the UTech Lab and sound studio. It is a digital center that offers professional equipment, hardware and software		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	**Create digital stories creations** Students work in groups for writing scripts using history and museums' materials related with science with priority in using educational software for creating movies.	Teacher balances the outcomes of the creative educational process.	**Exhibition of museums, geometrical shapes, science knowledge**

6. Additional Information

As a member of the writing group for educational materials in the "Piraeus Bank Group Cultural Foundation (PIOP)" within the action "Network Pausanias 2.0: from the School to the Museum", we have presented the connection of 6 Museums PIOP with the school knowledge of mathematics and science of the secondary school. There are many examples of how STEM teachers could provide valuable innovative proposals for the implementation of educational teaching scenarios and worksheets for organizing educational visits, linking museums with schools.

The goal is to inform teachers authorized by the Ministry of Education with educational material that can be exploited and prove that the museum is a living space, a potential extension of the classroom in the light that the students use the knowledge they acquire at school in order to understand the importance of the reports and exhibits.

But also as member of Erasmus+ program titled "Cinemaths Paradise" the exhibition of museums have been expanded in creating digital stories.

Mathematics

Mathematical and geometrical concepts and computational methods could be linked to the objects in each museum, which aims at fostering and exercising flexibility in the way of geometric and critical thinking is used as a tool to study the properties and justification of geometrical shapes.

In the Silk Museum of Soufli:

Traditional dresses fill in geometric shapes, which recognize that it is divided, and its properties.

Activity: Reeling or the unwinding of the cocoon's thread

Questions:

i) The geometric shape that is forming around the wooden wheel is A. Triangle. B. Square. C. Regular Hexagon. D. Rectangle.

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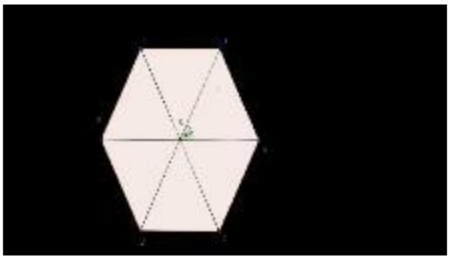

ii)What are the properties of the six triangles formed in geometrical shape?

iii) If we want to measure the length of thread we wrap once around the object then we have to calculate: A. At the perimeter, B. The area of, C. The length of the wood.

iv) If you know the distance between the wheel center by a top of the example D is R = 0,80m, then the length of each side is: A. Equals R B. double the R C. Sextuple with R.

Physics

Museum of Industrial Olive-Oil Production of Lesvos

The whistle marks the start of the working factory with the sound they produce.

Activity: Based on knowledge of physics fill in the gaps with one of the words indicated in brackets, in the following statement, which describes how to create the sound:

Questions: The ……………………. (Movements, oscillations, turbulence) of the air forces create ………. ……………. (Acoustic, mechanical, water) waves which propagate in it and called sound waves. Because the air molecules move in the wave propagation direction, the sound waves are ……………………… (linear, cyclic, longitudinal , transverse) waves.

Rooftile and Brickworks Factory Museum of Nikolaos and Spyridon Tsalapatas, in Volos (Thessaly)

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Questions:

i) If it starts at time t = 0 from the position A, and in time t=5min arrive to point B that the distance from A is 1000m in which time will be arrive to C that it's distance is 2000m from the A?

ii) If the trolley reaches the plant at time t = 15 min.

How long it took from the point B to the factory?

iii) If you know the speed of the trolley is stable throughout the stroke and the formula for calculating it. Filling in the gaps in the data, which will replace the press and then to calculate the speed, moving from A to B?

Distance B from A: X = …………………

Time taken to move from A to B: t = …………..

Speed= …… / ……


i) The electricity is ……………………….. …………. …… charged particles.

ii) The electrical current is given by the formula ……………………

iii) The unit of electrical current is …………….

iv)The instruments measure the electrical current called ……………….

v) Any apparatus in which a form of energy is converted into electrical called

……………………….source.

vi) The machines flown by electric current when the switch is ……………………

The Environment Museum of Stymphalia

One of the basic materials of livestock exposed to the Museum is the bells.

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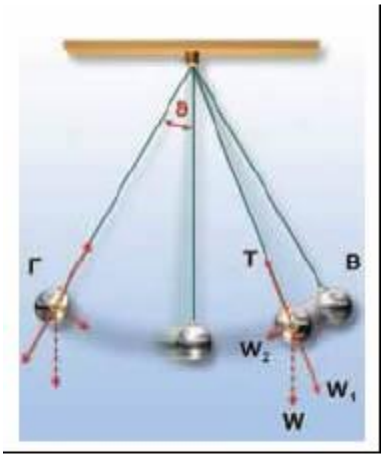

Questions: i) Choose the correct answer:

How it is called the movement of bells?

ii) Circle three of the following physical quantities are used to describe the oscillation:

Speed, frequency, speed, strength, width, weight, power, period, time, length.

iii) The most common practice of identifying animals from breeders is the sound of bells.

The ………………… of the air forces create mechanical waves which propagate in it and called …………. ……… waves.

iv) A farmer in the area of Lake hears the sound of the bell of at time t=20 sec. The velocity of sound is 340 m / s. Calculate the frequency and wavelength.

Chemistry

The Environment Museum of Stymphalia (Cont.)

Activity: How was the Stymfalia lake formed?

Questions:

i) Choose the correct answer.
The basic chemical compound which has contributed to the formation of the lake is:

A. Calcium carbonate (limestone)
B. Sodium chloride
C. Potassium nitrate
D. Hydrochloric acid

ii) Fill in the blanks with one of the words given in brackets on these proposals chemical reactions, which give the product as a compound that has contributed to the formation of the Lake:

Acid + base = …………………… + Water (acid – salt- base- Hydrogen chloride-calcium-Clay)

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Carbonic acid + calcium oxide + water ……………………….

(Calcium carbonate oxide of calcium nitrate carbonate carbon-carbon acid clay)

iii) Based on the above chemical reactions proposals to fill the chemical elements that are missing from the following reaction:

iv) Fill the gaps on these proposals, which refer to the chemical properties of the salts:

- The salts are ……………………… substances widely distributed in nature.
- Most components of the ………………….. ………………. bark …… are salts.
- Calcium sulfate (CaSO4) is ……………………… salt, because in 100 g of water at 25o C can dissolve the very 0.21 g calcium sulfate

Activity: Mathematical calculations

Questions

i)

1. The values of the amounts 'kg olives' collected from the olive grove and 'kg oil' produced at the mill is like figures.
2. If you increase the "kg olives 'collected from the grove; then will double the" kg oil' produced at the mill.
3. If you reduce the 'kg olives' collected from the grove 'then it halved the "kg oil' produced at the mill.

ii) You can help the grower, by completing the following table, based on your mathematical skills, calculate how many kilos of oil will produce, if transferred to the mill one ton Kalamata olives 25% yield;

Geometrical calculations

The Open Air Water-Power Museum

Activity: Geometrical calculations. Perimeters, Areas and volume of materials.

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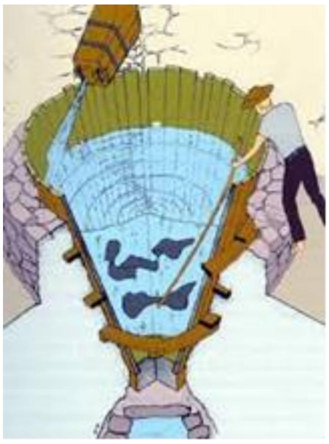 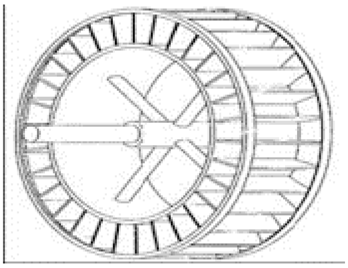 

All educational scenarios, guides for teachers and worksheet for each museum are published in: *http://www.piop.gr/el/Activities/Pafsanias.aspx*

Students team working for creating movies and animations

https://youtu.be/4GexvxI6vJo

https://youtu.be/p0QAyQh09EQ

https://youtu.be/EaBp8iopIOk

https://youtu.be/yTIldzEJjaQ

https://youtu.be/AQNoFMhg5L8

https://youtu.be/oOyEcUKGzac

https://youtu.be/pM1WLdELkhA

https://youtu.be/TvHeB7UPrLI

https://youtu.be/oOyEcUKGzac

https://youtu.be/dv8zEkKyW00

7. Assessment

For quantitative assessment we recommend the use of the "Science Motivation Questionnaire II (SMQ-II) ' 2 (Glynn, et.al, 2011; maximiliane, Schumm, Bogner, 2016) that is addressed to students

8. Possible Extension

Through this project students learn about scientific concepts by combining different domain areas, and by realising that a scientist use his/her knowledge to find solutions to everyday problems. By learning more evidence about a field and by cooperating with others we can realise what we learn. The combination of different ways of learning helps students to find their own interests and skills and feel useful. This project can be expanded on other domain areas, such as creating movies on science.

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D3.2.34. “Multi – maker” Scientific Event

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Zacharoula Smyrnaiou,Menelaos Sotiriou,** **Eleni Georgakopoulou, Konstantina Kotsari**
Code:	D 3.2.34	**Contributors:**
Version & Date: 31/10/2017		**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

It is a multi- disciplinary approach. Subject Domains are STEM (Mathematics, Physics, Chemistry, Biology etc.)

1.2 Type of Activity

- Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).
- Educational Activities that promote school- research center collaboration.

It is a local activity.

1.3 Duration

The duration of the whole activities is 1 day.

1.4 Setting (formal / informal learning)

The setting is formal and all the activities will take place at school.

1.5 Effective Learning Environment

- Arts-based: The students will make their own drawings, comics, stories and representation of scientific notions. They are going to express what they learn through art activities on a different way.
- Dialogic Space / argumentation: Students are going to discuss the different ways of art representations and decide the ways they are going to show and present the scientific notion.
- Communication of scientific ideas to audience.

2. Rational of the Activity / Educational Approach

2.1 Challenge

One of the main problems of the most school systems, included the Greek education system, is the students' lack of motivation. Nowadays students are not interested in STEM Education, as they think that science education is irrelevant to their lives. The majority of students cannot connect science education to their everyday lives. On the other hand, intrinsic motivation is the form of motivation comes from within. Children are naturally curious and interested in learning, exploring, and mastering challenges. We propose that engaging students with interactive science activities with the use of digital tools will increase the intrinsic motivation of the student.

The use of technology from the students is really common today. Students use internally technologies on their everyday lives. The problem of the distance between school knowledge and students' everyday needs is obvious, when students are not encouraged by the teachers to link their hobbies to educational practices or when the teachers focus on old, traditional educational methods, techniques and means. However, technologies can be really useful as educational methods, because they do not only challenge students' motivation but they also help them to approach knowledge on different ways (Smyrnaiou, et all. 2012).

In addition, the difficult scientific notions acquire a different way of thinking and teaching, where modern pedagogical framework is taken into account and is adjusted to basic principles, such as the use of different cognitive semiotic systems of the representation of scientific knowledge. Computer equipment and technology based environment intended for education and training using new communication and information technologies (ICTs) contribute to the modification of the contexts of teaching and learning.

The lack of scientific literacy means that students do not make their own decisions about science and social issues and they have not the appropriate skills to interact between social and personal dimensions. On 21st century, this problem is really crucial as it means that students are not interested in nowadays societal challenges but they also may not have the appropriate skills to do so. Greek students cannot build explanations and justify their thesis about nowadays problems and creative ideas could help them to these directions (Smyrnaiou et all, 2017). In addition, Greek educational system is exclusive for some students. Students with learning difficulties or disorders are, unfortunately, excluded from learning processes. Therefore, Inquiry Based Science Education (IBSE) enhances students' interest in science and has been proved to be an appropriate teaching method for all students, from the most "weak" to the most "capable" (Rocard, 2014), as it enhances students' comprehension (Chu, 2011).

The teaching methods are, also, old or inappropriate for their acquisition of knowledge, as these are not creative and challenging. A combination of different ways of creative teaching, such as comics, digital storytelling, drawing and the use of everyday things and materials for the representation of scientific notions can be a useful solution not only for the students but also for the children. Multiple representations of scientific concepts determine and influence meaning generation.

2.2 Added Value

Students will learn to think on different ways. There is not only the traditional way of learning and they will realize that if they combine art, digital sources, text comprehension and drawing, then they can acquire knowledge more analytically.

Different semiotic systems, also, help, students to express their feelings. At the same time, as the arts are not only an act of self- expression but also a vehicle for human understanding, students will learn to support their thesis and express their own ideas. They will be engaged in argumentation processes, which provide them with a better insight into the nature of scientific inquiry.

As they are going to be engaged in different activities, students will have the opportunity to discover in what they are really interested in. It is really important for students to realize that there is not only one way of developing themselves and they may start being interested in scientific careers.

3. Learning Objectives

3.1 Domain specific objectives

This Initiative's domain specific objectives are to:

- help students to search for scientific data to fully represent a scientific phenomena
- help students realize and explain the scientific phenomena
- help students represent scientific phenomena
- help students link scientific knowledge to their everyday lives
- Get students interested in science and research
- Initiate contact between students and other professionals (for example researchers))

3.2 General skills objectives

In the context of this Demonstrator, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Realizing that they acquire knowledge only when they are able to express and represent it on multiple ways.
- Studying the science and technology of image reproduction and processing
- Scientific interconnection of science with aspects of art (comics, digital storytelling, drawing, visual representation etc.)
- Make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.
- Develop spirit of cooperation and teamwork
- Connect the science classroom with professionals, parents and local communities

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator deals with new scientific notions, such as gravitational waves or the dark matter. These notions are not included in Greek school curricula, although there are new findings on these fields. Therefore, the aim of this demonstrator is to make these notion familiar to the students, to be aware of new, modern scientific findings and to make them understand that there are creative ways to deal with such phenomena.

This demonstrators consists of three parallel sessions:

- **Session 1: Presentation of 4 stories- Drawing/ Painting**

These activities are based on scientific storytelling and drawing. Students from 1st and 2nd Class of Primary School talk about the combination of science and fairytales. Then they make drawings so as to represent on another way what they understood from these stories.

- **Session 2: Presentation and experiments on gravitational waves and creative activities - theatrical representation.**

These activities are based on representation of gravitational waves with constructions. The 5th and 6th Class of Primary Schools deal with gravitational waves.

- **Session 3: Discussion - presentation of topics on the universe and the dark matter, Use of digital media - Comic creation**

These activities are based on digital storytelling and creation of comics. Two other classes (3rd and 4th classes from Primary Schools) focus on black matter.

- **A final presentation**

At the end of all events students are going to present the whole activities in a common classroom, so as to deal with these issues on a creative way, combining different forms of Art.

4.2 Student needs addressed

This multipurpose scientific event is a school event, on which:

a) Students will acquire new knowledge on different levels. As far as cognitive development concerned, students will build knowledge about scientific concepts. They will also learn to recognize the main keys of scientific notions to the everyday phenomena and they will link their knowledge to everyday needs.

b) Students will also learn to negotiate their ideas with others. They will learn to make dialogue with other students about different representations and they will develop critical thinking. As they will cooperate with other students, they will learn to build explanations and justify their choices. Through this procedure, students will identify scientific issues, make questions, collect data, explain and communicate their thinking

and the final conclusions. This transformation of initial ideas into grounded concepts helps them to become acquainted with the concept of learning science creatively.

c) Students expand the ways of thinking and learning. The ways of doing Science and Mathematics have been advanced rapidly. Hence, it is vital to students and future citizens with the ability to adapt and thrive in a fast-changing environment.

d) Additionally, multiple representations of scientific concepts determine and influence meaning generation by students. Thus, the utilization of texts that incorporate more than one semiotic systems, such as written and spoken text, images and motion, and which are commonly accessible with digital technologies, can provide assistance to students, even on students with learning difficulties. It seems that IBSE, enhanced by digital technologies, has the potential to help students overcome the obstacles they encounter, strengthening their skills and interest in science and to help them generate scientific meanings.

5. Learning Activities & Effective Learning Environments

Science topic: STEM, Mathematics, Physics, Chemistry, Biology (Relevance to national curriculum but also Introducing new notion to primary school students) Class information Year Group: All classes pf primary school Age range: 6-12 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.* printed questionnaires, teleconference, etc.) painting, colours, computers, material such as fabric and marbles, plasticine Cameras *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The preparation activities will take place mostly in the classroom and in technology labs. *Health and Safety implications? A teacher guides and helps students during their activities.* *Technology? Computer and internet access* *Teacher support? scaffolding*
Prior pupil knowledge Before the implementation of the activity, teachers tried to build on potential students' prior knowledge and science beliefs through various science materials from different sources, conversations during science classes, field trips. Other techniques used for activating background knowledge include asking questions about specific science topics, making associations, and using demonstration or multimedia to enrich background knowledge.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Session 1: Presentation of 4 stories- Drawing/ Painting

These activities are based on scientific storytelling and drawing. Students from 1st and 2nd Class of Primary School talk about the combination of science and fairytales. Because of the students' little age, the discussion is about simple notions, such as planets, stars etc. Then they make drawings so as to represent on another way what they understood from these stories.

Session 2: Presentation and experiments on gravitational waves and creative activities - theatrical representation.

These activities are based on representation of gravitational waves with constructions. The 5th and 6th Class of Primary Schools deal with gravitational waves.

Session 3: Discussion - presentation of topics on the universe and the dark matter, Use of digital media - Comic creation

These activities are based on digital storytelling and creation of comics. Two other classes (3rd and 4th classes from Primary Schools) focus on black matter.

At the end of all events students are going to present the whole activities in a common classroom, so as to deal with these issues on a creative way, combining different forms of Art.

Assessment	**Differentiation**	**Key Concepts and Terminology**

Students are engaged in workgroup assessment processes throughout the sessions.	*How can the activities be adapted to the needs of individual pupils?* *This approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realization. During the inquiry phase all students will participate and contribute with relevant to their interest data.*	**Science terminology:** **Maths, Geometry, Physics, Newtonian physics, nuclear physics, astronomy, dark matter, black holes, gravitational waves, biology,** **Arts terminology:** **visual representation, music, storytelling, comics, digital representation**
Session Objectives: During this scenario, students will students will deepen their understanding on scientific concepts and phenomena, using their creativity and imaginatio		
Learning activities in terms of CREATIONS Approach		

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied	**Session 1:** Students talk about the combination of science and fairytales. Because of the students' little age, the discussion is about simple notions, such as planets, stars etc. **Session 2:** Students talk about gravitational waves and other scientific notions following a specific scenario (see below). **Session 3:** Students discuss about the universe. The film "Interstellar" (5 min.) (https://www.youtube.com/watch?v=0vxOhd4qlnA is used as a prompt to challenge students' initial ideas.	The teachers try to attract the students' attention by eliciting students' relevant questions and showing relevant videos.	

	learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	**Session 1:** Students give their answers and they try to find some fairytales about these notions. Some fairytales are also given to promote further discussion. **Session 2:** Students investigate the data. They compare the videos and notice all the parts of gravitational waves. **Session 3:** The students: 2) watch videos about the universe and search for information on the internet (20 minutes) https://www.youtube.com/watch?v=oHioOukbOTA (7.25 - 12.25, 19-23.20) 3) observe objects through worldwide telescopes and recording them. (5 - 10 minutes)	The teacher identifies possible misconceptions.	

		4) observe the black holes with word wide telescope and some videos http://hubblesite.org/explore_astronomy/black_holes/modules.html (5- 10 minutes)		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	**Session 1:** The discussion about the scientific notions and the fairytales go on and the students try to find the characteristic of each notion. **Session 2:** 30 students will draw masks related to the themes of the universe10 students will create sounds related to the universe and gravitational waves 20 students will represent the gravitational waves with their bodies. A student will be one scientist who writes a paragraph and tells the discovery of gravitational waves	Act as a facilitator of the process	**Painting/ drawing, creating music, body representation of gravitational waves, storytelling**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the	Students evaluate their explanations and they discuss about what they have made. **Session 3:** Students provide explanations comparing photos from space objects. A text for black holes is given and they answer some questions (10 minutes).		

	relative merits of the explanations they formulate, *playing* with ideas.	Students then write their own texts about the black holes.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	**Session 1:** This section is the same as the above because of the students' little age. **Session 2:** Students explore the topic again, find connections from all the data and use some fabric and marbles to represent the motion of gravitational waves. **Session 3:** Students try to collect the basic characteristics of dark holes. 1) View video for black holes. https://www.youtube.com/watch?v=4cGqxWtT-_0 (1.2.40 - 1.6.40) (5 minutes) 2) Students read a text for dark matter and answer questions (10 minutes). 3) View some power points for dark matter mapping. 4) Quick discussion and puzzle (https://www.esa.int/esaKIDSen/SEMU7NSVYVE_ga.html).	Teachers follow the discussion and enhance students' participation.	**2. Representation of the motion of waves by using everyday material, such as balls.**

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	**Session 1:** Students make some drawings of planets, universe, etc. **Session 2:** Students communicate with professionals in order to get help about scientific notions and communicate their findings by implementing a science visual representation on gravitational waves. **Session 3:** Students communicate with professionals in order to get help about scientific notions and communicate their findings.		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended	**Session 1:** Students discuss about their paintings and make a poster. **Session 2:** Students represent with their bodies and voices but also with the music that they have composed the motion and the sound of gravitational waves. **Session 3:**	Teacher balance the outcomes of creative educational process with	**Visual representation of the motion of gravitational waves, final performance** **Students' comics to**

	inquiry learning and the curriculum and assessment requirements of education.	Students create their own comics to communicate the acquired knowledge	assessment features.	**communicate the acquired knowledge**

6. Additional Information

Our first participation included the organisation of school events and activities on which 180 students of primary school participated.

The programme of the Event and Activities:

"Multi – maker" Scientific Event

Workshop Plan:

<table>
<tr><th>Timing</th><th>Method</th><th colspan="3">Session</th></tr>
<tr><td>8:20</td><td>Slides, Videos, Discussion, Scientist Presentation</td><td colspan="3">Presentation - Familiarization with Modern Science Issues
• 1st – 2rd Grade (8:30 – 9:40)
• 3th – 6th Grade (8:30 – 9:40)
(different presentations to younger and older groups of students)</td></tr>
<tr><td>9:40</td><td></td><td colspan="3">Break</td></tr>
<tr><td rowspan="3">10:00</td><td rowspan="3">Digital Story telling Software, Other digital tools, cameras,</td><td colspan="3">Modern Science Matters – Experimentation (Parallel Sessions)</td></tr>
<tr><td>1st& 2ndGrade
"Make your own fairy tale"</td><td>3nd – 4th Grade
"Gravitational Waves"</td><td>5th – 6th Grade
"Digital Storytelling, Make it Dark"</td></tr>
<tr><td>Use colors, plasticine (relevant with the topic of the presentation)</td><td>Mini Theatrical Show of students</td><td>Use everyday tools to create a story about gravity waves.</td></tr>
<tr><td>11:30</td><td></td><td colspan="3">Break</td></tr>
<tr><td>11:45</td><td>Video, Scene, presentation</td><td colspan="3">Presentation of workshop delivery
• Mini Theatrical Show of students</td></tr>
</table>

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Timing	Method	Session
12:25		**Break**
12:35 – 13:15	Writing and Discussion	**Reflection - Evaluation** 3rd – 6th Grades (Discuss – Fill in Questionnaires)

Resources required: Story Telling Digital tools, presentation tools, plasicine, markers, pens, sheets.

Affiliations: Science View, National and Kapodistrian University of Athens

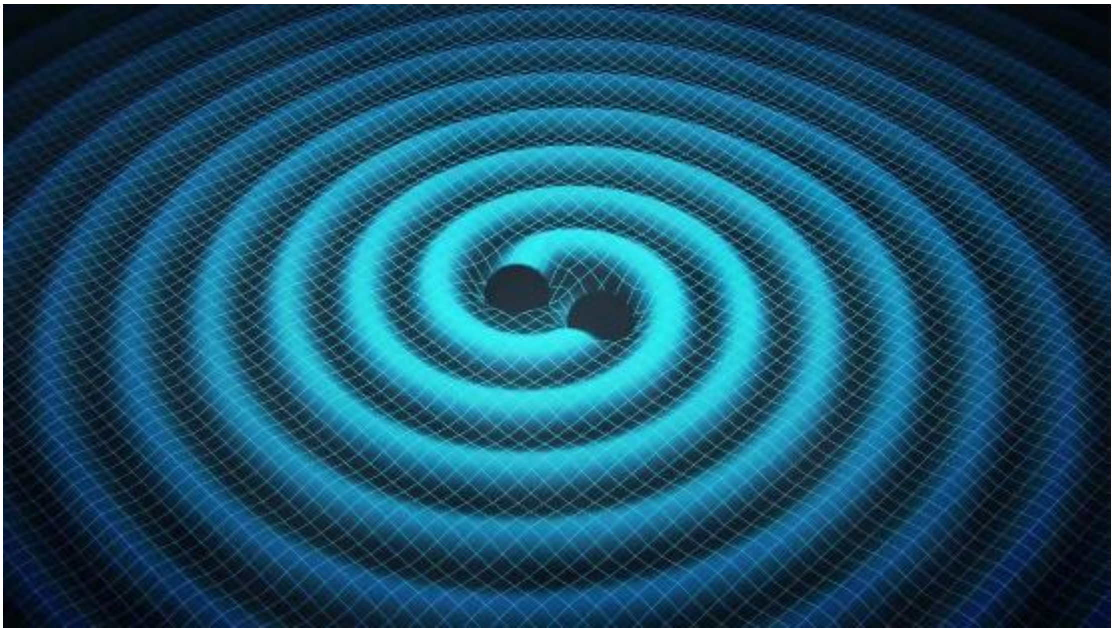
Exemplary Course Planning for Session 1:

- **Discussion** – presentation of the topic of the scientific explanations of the 4 seasons.
- **Brainstorming/ motivation**: Question about 4 season scientific explanations for eliciting pupils' initial ideas.
- **Motivation / Inquiry phase**: Narration of special 'scientific fairytales' for 4 seasons.

Use of narration videos: https://www.youtube.com/watch?v=EoXrXhN3TI4
https://www.youtube.com/watch?v=h8Nc6i7J9ic

- **Creative application of acquired knowledge**: Drawing the 4 seasons in a scientific way and communication:

Learning Scenario for the Session 2: Gravitational Waves



1. Identity of Scenario

- **Subject: Physics**
  - Gravitational Waves
- **Topics:**
  - ✓ Gravity
  - ✓ Space, time
  - ✓ Dark holes
  - ✓ Gravitational Waves
  - ✓ The importance of the discovery
  - ✓ Representation of gravitational waves

- ✓ Discussion, Evaluation

2. Objectives

Main Objectives:

Cognitive Objectives:

The expected objectives, as they appear and relate to the subject matter of the scenario, are summarized in that students should:

- Understand the basic concepts of Physics, eg gravity, speed, etc., which are an indispensable and integral part of the understanding of the concept of gravitational waves.
- realize the relationship of the above concepts and their interaction for the creation of gravitational waves.
- Combine the knowledge of Physics with their everyday life to better understand scientific knowledge

Pedagogical Objectives

The pedagogical and learning objectives that are approached by the scenario aim to further develop and:

- combine different ways of conquering / representing knowledge.
- cultivate their creativity
- work together to achieve a common goal

3. Activities

1. Discussion about gravitational waves, videos.

- Q1: I do not understand Physics, it's very difficult! Do you know what the universe is? The galaxy, the planets, the speed, the gravity; (Scaling questions from the best known to less well-known and difficult to cultivate the question and interest.
  Q2: It's not all that difficult! We have them in our lives, we see them, we feel them! We observe them every day!
  Q1: What do you mean? I also notice gravity, space, time; Where is he and I do not see it!
- **Gravity, an "irresistible" force.**

Q2: What is it? Why do not we fall from the ground? Would you like to see?

https://www.youtube.com/watch?v=MJBa7NfF9kw (4: 52-6:25)

Q1: I did not understand anything! What are these falling apples?

Q2: Look now!

https://www.youtube.com/watch?v=jwPc0kK9VHU

E1: A! I understand!

- Newton, a very great scientist, managed to compute the power of gravity exercised in every body.

-How does gravity work?

Q2: To see this, we need to make a journey into the history of the sciences, with lots of experiments and great interest !!

- **Space:**

WORKSHOP 1: Shake your hands fast! Do you feel the air? Blow everyone to your friend! It is everywhere around and surrounds us, it is in our "space". But what is space? Have you ever wondered? Possible examples, such as expressions of space (I am in my space, it has space, it takes a lot of space, etc.) / Discussion

Now, get up, play by doing a "fantastic" experiment!!

We are a large group of savvy scientists, serious and quiet. Let's empty the "space" here in the center!! (the desks at the edge) And now, let's just imagine we'll blow all the air off!! (we go into space, suck the air and blow it out). Come in, and close your eyes to let go of light and heat.

Let's imagine, then, that we have pushed everything ... that we are in a vacuum ...Let your hands completely loose and, carefully, turn around!! (The teacher goes to the center with the clock) (Suddenly it hits an alarm clock) "open your eyes" What did you feel in your hands?

Discussion: If the experiment was done in a vacuum, you would feel again that you are spinning, because you would feel this power pulling your hands out.

You would feel that you are turning around in the SPACE!

Space is not just an empty scene but it interacts with everything!!

- **Time**

WORKSHOP2: E1: Now I understand what space is. But I have another question! Time what is it? Possible examples of time expressions / Discussion

• I do not have time to play.

• Every year we go on holiday.

• It ends, we do not have much time.

• We made a trip in the past and learned about the works Pericles did in ancient Athens. (PAST).

• In the future is it possible to travel? (FUTURE)

Is it absolute?

Q2: And if I told you that the journey in the future is feasible? -> WORKSHOP 2: video experiment with a clock on a traveling plane

https://www.youtube.com/watch?v=pTJdv3W3nuc&list=PL657346ED515A25E5&index= (2 15: 18- 16: 30 (BEST AT 15:39)

- **The speed of light**

What is speed? Discussion (the ratio of the distance in time)

WORKSHOP 3:

1. A student moves in a straight line, and we find his speed from the distance he has spent in the space at a certain time. Scientists have measured the speed of light, and found they are always stable!!

2. Paintings of gravitational waves

3. Small stories that children will write (very small texts, like fairytales, creating gravitational waves, etc.)

4. A child plays music or sings or we can bring some materials to guess what sound the gravitational waves would have.

5. Role playing, e. g how a scientist discovered them, etc.

6. Representation of gravitational waves through the theatrical (as you thought it too) to be the final act

- **The relativity of space and time**

WORKSHOP 4:

Let's do an experiment!!

One student catches the ball, one flies. At first the student is stationary, throws the ball to the other student. Then he takes on forays and runs it again with the same strength. How does a student perceive his power? Conclusion of experiment?

E1: Now I understand why we did this! (When we give extra fora to something, it gets faster)

E2: One of the greatest scientists who have existed, Einstein, had the following thought: if we accelerate a light source, then, based on the laws of physics known at that time, the speed of light should be increased. However, this did not happen, but it remained the same.

Q1: How is that possible? Now we did not say that when we push something, its speed gets bigger;

Q2: And Einstein did ask yourself that!

Q1: I mean, I'm a little Einstein;

E2: And then he had the following thought: since speed depends on the movement in space and the passage of time, then in order to remain stable, these two should be changed. His theory therefore suggested that Space and Time related and altered!!!

Q1: So if I have the speed, the space and the time, to keep the speed constant, while changing the space and the time, it means all this is connected!

- **The black holes**

E1: In addition to the planets, the sun and the stars in the universe, there are the black holes in the universe!

Do you know what it is?

https://www.youtube.com/watch?v=I_88S8DWbcU

- **The gravitational waves**

WORKSHOP 5: REPRODUCTION OF WARNING WAVES

https://www.youtube.com/watch?v=ZkURrrACG0g

https://www.youtube.com/watch?v=y0orOwQgcCM

https://www.youtube.com/watch?v=4GbWfNHtHRg

- **Final Activities**

Separating students into groups:

2. 30 students will draw masks related to the themes of the universe
3. 10 students will create sounds related to the universe and gravitational waves
4. 20 students will represent the gravitational waves with their bodies.
5. One scientist who writes a paragraph and tells the discovery of gravitational waves
6. Theatrical representation of gravitational waves.

Exemplary Course Planning for Session3:

Discussion - presentation of topics on the universe and the dark matter, Use of digital media - Comic creation

- **Brainstorming/ Motivation:** Use of web tool **popplet** (https://popplet.com/)
  Eliciting students' initial ideas
  Do you like science fiction films? Have you seen any? What is space made of?
  (The Interstellar movies was used as a prompt) (https://www.youtube.com/watch?v=0vxOhd4qlnA)

- **Motivation / Inquiry phase:**
  Students watch a video about space as a prompt to initiate discussion. https://www.youtube.com/watch?v=oHioOukbOTA
  They search the internet to find information about space.
- **Experimenting/ observing**
  Identifying, observing and registering information about space objects with the use of the world wide telescope and http://hubblesite.org/explore_astronomy/black_holes/modules.html

- **Further enhancement of inquiry**
  Use of reading and video prompts (https://www.esa.int/esaKIDSen/SEMU7NSVYVE_ga.html https://www.youtube.com/watch?v=4cGqxWtT-_0)
  to enhance understanding about black holes and dark matter.

- **Creative application of acquired knowledge** – Use of the web tool toondoo http://www.toondoo.com/
  Students are asked to collaborate for the creation of a comic that best represents the main principles of dark matter.

Η ιστορία του Σύμπαντος

Το μυστήριο του σκοτεινού Σύμπαντος

Η συνηθισμένη ύλη δημιουργεί οτιδήποτε μπορούμε να δούμε, να οσφρανθούμε ή να αγγίξουμε. Αυτή η ύλη – η οποία είναι κατασκευασμένη από άτομα – επίσης δημιουργεί πλανήτες και αστέρια.

Όλα τα αντικείμενα που είναι κατασκευασμένα από άτομα έλκουν το ένα το άλλο ανάλογα με την ποσότητα της ύλης που περιέχουν. Αυτό είναι το αποτέλεσμα της βαρύτητας και εξηγεί το γιατί ένα μικρό, χαμηλό σε ποσότητα μάζας αντικείμενο όπως είναι ένα μήλο πέφτει προς την κατεύθυνση ενός πολύ μεγαλύτερου σε μάζα αντικειμένου – της Γης.

Οι αστρονόμοι πιστεύουν ότι πρέπει να υπάρχει επίσης ένα άλλο είδος αόρατης ¨σκοτεινής ύλης¨ η οποία είναι διασκορπισμένη σε ολόκληρο το Σύμπαν. Μελετώντας τον Γαλαξία και πολλούς μακρινούς γαλαξίες, έχουν ανακαλύψει ότι η ορατή ύλη από μόνη της δεν μπορεί να γίνει η αιτία για το πόσο γρήγορα τα αστέρια περιστρέφονται σε αυτούς. Από μόνη της, η κανονική ύλη δεν θα μπορούσε να δημιουργήσει αρκετή ενέργεια έτσι ώστε να κρατήσει αυτούς τους γαλαξίες μαζί.

Οι επιστήμονες μπορούν επίσης να πουν ότι υπάρχει κάποιο άγνωστο υλικό στο διάστημα ανάμεσα στα αστέρια, γιατί η βαρυτική έλξη του επηρεάζει το πέρασμα του φωτός των αστεριών που ταξιδεύει προς τη Γη. Η ύλη – και η συνηθισμένη και η σκοτεινή – μπορεί να συμπεριφερθεί σαν ένα μεγεθυντικό γυαλί, που διπλώνει και διαστρεβλώνει το φως από τους γαλαξίες και οτιδήποτε ομαδοποιείται πίσω από αυτήν. Οι αστρονόμοι μπορούν να χρησιμοποιήσουν αυτό το αποτέλεσμα, που αποκαλείται βαρυτικός εστιασμός, για να χαρτογραφήσουν την διανομή της σκοτεινής ύλης.

Μόνο περίπου 15% της ύλης στο Σύμπαν είναι κατασκευασμένη από άτομα. Το υπόλοιπο είναι σκοτεινή ενέργεια. Όμως, κανείς δεν γνωρίζει από τι είναι φτιαγμένη η σκοτεινή ύλη. Γνωρίζουμε πολύ καλά ότι δεν απορροφά, εκπέμπει ή αντανακλά φως, επειδή κανένα από τα επιστημονικά μας όργανα δεν μπορεί απευθείας να το ανιχνεύσει.

Πολλοί επιστήμονες πιστεύουν ότι η περισσότερη σκοτεινή ενέργεια είναι κάποιο άγνωστο υποατομικό (μικρότερο από ένα άτομο) σωματίδιο που αλληλεπιδρά μόνο πολύ αδύναμα με την κανονική ύλη. Εάν αυτό αληθεύει, δισεκατομμύρια από αυτά τα σωματίδια θα έχουν περάσει διαμέσου του σώματος σου μέχρι την στιγμή που θα έχεις τελειώσει την ανάγνωση αυτού του άρθρου. Πειράματα που έχουν αποκρύψει το βαθύ υπόβαθρο ίσως μία ημέρα μετρήσουν την παρουσία ενός τέτοιου σωματιδίου που περνάει μέσα από το σώμα σου, λύνοντας τελικά το μυστήριο του τι πραγματικά η σκοτεινή ύλη είναι.

Ερωτήσεις

1.Από τι εξαρτάται η ένταση της βαρυτικής έλξης των σωμάτων ?

………

………

……
…………………………………………………………

2.Πως δικαιολογούν οι επιστήμονες την ύπαρξη της σκοτεινής ύλης?

……
……
……
……
……
…………………………………………………………………

3.Τι γνωρίζουμε σχετικά με την απορρόφηση και την εκπομπή φωτός από την σκοτεινή ύλη?

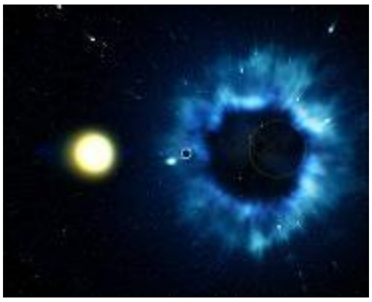
……
……
……
…………………

4. Τι πιστεύουν οι επιστήμονες ότι είναι η σκοτεινή ύλη?

……
……
……
…………………………………

Η ιστορία του Σύμπαντος

Οι μαύρες τρύπες



Οι μαύρες τρύπες είναι τα πιο περίεργα αντικείμενα στο Σύμπαν. Μία μαύρη τρύπα δεν έχει επιφάνεια όπως ένας πλανήτης ή ένα αστέρι. Αντί για αυτήν, είναι μία περιοχή του διαστήματος όπου η ύλη έχει καταρρεύσει επάνω στον εαυτό της. Αυτή η καταστροφική κατάρρευση έχει επιφέρει ως αποτέλεσμα μία τεράστια ποσότητα μάζας να έχει συγκεντρωθεί σε μία απίστευτα μικρή περιοχή. Η βαρυτική έλξη αυτής της περιοχής είναι τόσο μεγάλη που τίποτα δεν μπορεί να δραπετεύσει – ούτε το φως ακόμη.

Αν και οι μαύρες τρύπες δεν φαίνονται, γνωρίζουμε ότι υπάρχουν από τον τρόπο που επιδρούν στην σκόνη, στα αστέρια και στους γαλαξίες που βρίσκονται κοντά τους. Πολλές από

αυτές περιβάλλονται από δίσκους ενός υλικού. Καθώς οι δίσκοι στροβιλίζονται γύρω από αυτές σαν δίνη, γίνονται εξαιρετικά καυτές και αναδύουν ακτίνες Χ.

Οι μαύρες τρύπες έχουν πολλά διαφορετικά μεγέθη. Πολλές από αυτές είναι μόνο λίγες φορές πιο μεγάλες σε μάζα από τον Ήλιο. Αυτές οι ¨αστρικές – σε μάζα¨ μαύρες τρύπες σχηματίζονται όταν ένα αστέρι μεγάλου βάρους, περίπου 10 φορές βαρύτερο από τον Ήλιο, τελειώνει τη ζωή του σε μία σουπερνόβα έκρηξη. Αυτό που μένει από το αστέρι – ακόμη αρκετές ηλιακές μάζες – καταρρέει σε μία περιοχή μόνο λίγα χιλιόμετρα απέναντι.

Οι περισσότεροι γαλαξίες, συμπεριλαμβανομένου και του Γαλαξία μας, έχουν υπερμεγέθεις μαύρες τρύπες στα κέντρα τους. Αυτές μπορεί να είναι εκατομμύρια ή δισεκατομμύρια φορές βαρύτερες από τον Ήλιο μας. Οι υπερμεγέθεις μαύρες τρύπες επίσης δίνουν δύναμη σε ενεργούς γαλαξίες και σε αρχαίους γαλαξίες που είναι γνωστοί ως κβάζαρς. Οι κβάζαρς μπορεί να είναι εκατοντάδες φορές πιο λαμπεροί ακόμη και από τους πιο μεγάλους συνηθισμένους γαλαξίες.

Τα αντικείμενα που πέφτουν μέσα στις μαύρες τρύπες είναι κυριολεκτικά τεντωμένα σε σημείο σπασίματος. Ένας αστροναύτης που θα τολμούσε να πλησιάσει πολύ κοντά και θα απορροφιόταν μέσα σε μία μαύρη τρύπα, θα γινόταν κομμάτια από τη συντριπτική βαρύτητα.

<u>Ερωτήσεις</u>

1.<u>Γιατί το φως δεν μπορεί να δραπετεύσει από μια μαύρη τρύπα?</u>

………
………
………
……………

2.<u>Πως γνωρίζουμε την ύπαρξη των μαύρων τρυπών?</u>

………
………
………
………
………
……………………………………………………………………

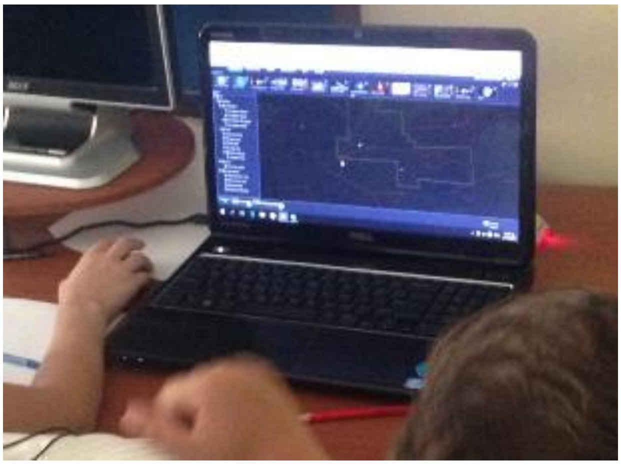
3.<u>Τι πιστεύουν οι επιστήμονες ότι βρίσκεται στο κέντρο του γαλαξίας μας?</u>

………
………

……
………………

4. Τι παθαίνει ένα αντικείμενο όταν πέσει μέσα σε μια μαύρη τρύπα.?

……
……
……
…………………………………



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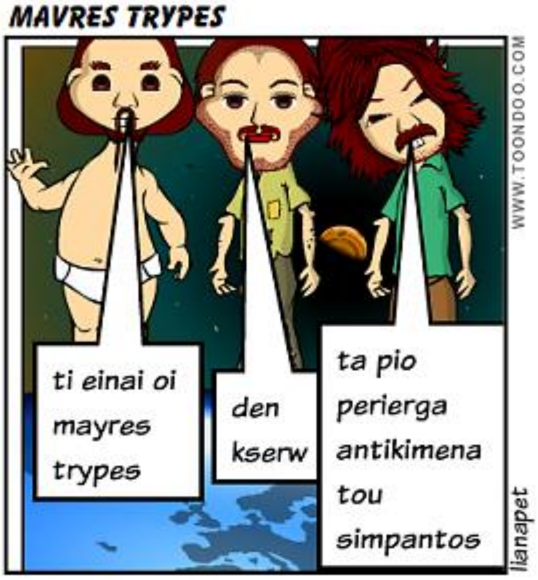
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kai i Gi apo tin alli pleyra






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7. Assessment

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of this Demonstrator.

For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)' (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

8. Possible Extension

This event may take place on others schools from all over Greece so as to become an international activity. On this way we can compare different artistic approaches and research the acquisition of scientific knowledge.

9. References

Chu SKW, Tse SK, Loh EKY, Chow K. Collaborative Inquiry Project-Based Learning. Effects on Reading Ability and Interests. Library & Information Science Research 2011, 33(3): 236-243.

Rocard M. Science Education Now: A Renewed Pedagogy for the Future of Europe. 2007. Directorate-General for Research, European Commission: Brussels; 2014.

Smyrnaiou, Z., Foteini, M., & Kynigos, C. (2012). Students' Constructionist Game Modelling Activities as Part of Inquiry Learning Processes. Electronic Journal of e-Learning, 10(2), 235-248. ISO 690

Scientific Stories:

www.youtube.com/watch?v=pSpXSVN10vI

www.youtube.com/watch?v=JFFU2lzdpvw

www.youtube.com/watch?v=h8Nc6i7J9ic

www.youtube.com/watch?v=EoXrXhN3TI4

Dark Matter:

https://www.youtube.com/watch?v=7xKFrdzhM2Y
https://www.youtube.com/watch?v=QAa2O_8wBUQ
https://www.youtube.com/watch?v=diGqS2yhPIM
https://www.youtube.com/watch?v=QAa2O_8wBUQ
http://www.smithsonianmag.com/science-nature/dark-energy-the-biggest-mystery-in-the-universe-9482130/?no-ist
http://discoverykids.com/articles/dark-matter/
https://www.esa.int/esaKIDSen/SEMX4EBE8JG_OurUniverse_0.html
https://www.esa.int/esaKIDSen/SEMU7NSVYVE_ga.html
http://www.mixanitouxronou.gr/o-galaxias-pano-apo-to-nao-tou-posidona-sto-sounio-i-fotografia-tis-imeras-sti-nasa/
http://www.esa.int/Our_Activities/Space_Science/First_3D_map_of_the_Universe_s_dark_matter_scaffolding
https://www.youtube.com/watch?v=HpriHQcIVV8

Gravitational Waves:

https://left.gr/news/exigisi-se-komiks-ma-ti-einai-ayta-ta-varytika-kymata-poy-akoyme-synehos
https://www.youtube.com/watch?v=MTY1Kje0yLg
https://www.youtube.com/watch?v=ZkURrrACG0g
https://www.youtube.com/watch?v=a3OQ7ek7t68
https://www.youtube.com/watch?v=hhbMpe17fzA
https://www.youtube.com/watch?v=BnmrFrUkBv0&list=PLVcnHoRTRAICKskPz6iz7tf9Um0BBiibd&index=1

D3.2.35 Mathematical tour on Art

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Argyri Panagiota Zacharoula Smyrnaiou, Menelaos Sotiriou, Eleni Georgakopoulou (NKUA)**	
Code:	D 3.2.35.	**Contributors:**	
Version & Date:	V0.1, 2/5/2018	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Geometry, Art

1.2 Type of Activity

- Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based). The activities suggested through this demonstrator are done on a local level, so it is a local activity.

1.3 Duration

6 months

1.4 Setting (formal / informal learning)

The activity is both formal and informal. The main scenario includes IBSL activities on school but also lectures with scientists and researchers and educational visits to Science Museums. The local community is also involved in a creative way.

1.5 Effective Learning Environment

The Effective Learning Environments according to the framework (D.2.3.) are :

- Arts-based
- Experimentation (Science laboratories and eScience applications)
- Dialogic Space / argumentation
- Visits to research centers (virtual/physical)

2. Rational of the Activity / Educational Approach

2.1 Challenge

How can we induce motivation for learning mathematics? How can we eliminate students' negative attitudes towards this? On Greek Curricula Mathematics play a dominant role as it is considered one of the main cognitive aspects of mental thinking. Despite their significance on development of thought, this subject is also really crucial for people's everyday lives. However, the scientific importance of Mathematic seems to be on a great distance to common students' views. Unfortunately, the majority of Greek students are negatively disposed to Mathematics, as they consider this subject extremely difficult. On the other hand, there are lots of teachers who teach Mathematics on a monotonous way, emphasizing only to the basic knowledge, without trying to explain in ti the students or giving examples on a more understandable way. As a result, students believe that Mathematics do not have any value, as they cannot find any relation to their everyday lives. This problem is really crucial not only because of the depreciation of Mathematics but also because students face them with fear. This lack of motivation against Mathematics explain not only this fear but also why most of the students do not want to follow such careers.

A the same time, teachers are not able to find the appropriate, creative way not only to teach Mathematics, but also to change students' opinions against Maths. Some of them do not have the appropriate knowledge, but some other do not know how someone can combine different semiotic systems to capture students' interest.

As a result, almost no one knows how to use some activities, which are familiar to students, such as a type of art activity, in order to make them more interested in Maths. On the other hand, even some teachers who want to use a more entertaining activity to capture students' interest, they forget that there must be also a cognitive impact. Therefore it is really helpful to learn by doing, to learn by having fun, to learn by creating something and to learn by using Art.

2.2 Added Value

Maths and art in general, although, (seemingly at least,) they constitute two separate - different spheres of human activity, they can be combined and provide us with creations which are an admirable blend of impressive complexity and astonishing beauty. Moreover, mathematics from ancient Greece until today have been playing an important role in the development of various forms of art. In all seasons prominent forms of art have been highlighted, which used mathematics as the key component of their art (Argyri, P., 2018).

Undoubtedly, Maths has an element of objectivity and is related with the logical part of humans unlike art which has the element of subjectivity and is mainly related to the emotional part. Art arises as the pure offspring of the human need for expression while Mathematics equally arises as the pure offspring of the human need for understanding, However both needs that differentiate humans from animals coexist in one and indivisible whole: human nature . So, the apparent difference in principle should have connecting bridges (Argyri, P., 2018). Therefore, it is a reasonable question: Are Art and maths interwoven concepts? Were they developed simultaneously and independently or is there a deeper way to connect them (Argyri, P., 2018, 2014, 2013)?

We believe that Maths and Art can be combined in a harmoniously way in order to represent scientific notions. Within science education, there have been attempts which focus on the consistencies of a semiotic system on others or on the connectivity of different semiotic systems (Smyrnaiou, Sotiriou S., Sotiriou M, Georgakopoulou, 2017; Smyrnaiou, Sotiriou M. Georgakopoulou, Papadopoulou, 2016, Smyrnaiou, Weil-Barais, 2003).

3. Learning Objectives

3.1 Domain specific objectives

The Mathematical Tour on Art domain specific objectives are:

"The interaction of mathematics and art from ancient Greece to the 21st century"

- Understand geometric properties through the visibility and critical examination of impressive constructions (architectural creations, monuments, paintings, mosaics).
- To develop a positive attitude towards mathematical science.
- Make use of their experience and apply the knowledge they have gained through the implementation phases of the project so that in a spirit of artistic creation and mentoring they can testify their own creations.
- Familiarize and cultivate skills in the use of new technologies to create geometric structures.
- Collaborating on activities with art designs in geometry and presentations.

3.2 General skills objectives

In the context of the Mathematical Tour on Art, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts and Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art
- Develop creative and critical skills
- Develop spirit of cooperation and teamwork by exchanging their views and trying to substantiate with arguments.
- Developing students' creativity by exploiting their artistic skills in conjunction with their geometrical knowledge
- Developing the spirit of research
- Learning to engage in the dialogue of all classes and to contribute with their ideas and assessments (Argyri, P.,2018)

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of Mathematical Tour on Art is to help students acquire mathematical thinking combing Maths to Art. We believe that Art, as a representative system, can represent mathematical relationships and can help student understand that Maths are a part of everyday life.

Moreover students understand that there is a combination between phenomenally different subjects and that combination and interdisciplinarity is a skill for their holistic development and critical thinking (Argyri,2018).

The idea of holding and organizing these activities begins with some initial research questions that were held by students, who were trying to answer them on all phases of these activities.

- Which is the effect of geometry on various art forms (architecture, painting, sculpture) from ancient Greece to the modern age?
- In what ways and how the relationship between mathematics and art is manifested?
- How and in what ways is the interpenetration between expressed math-art?
- How can we exploit new technologies to build artistic creations with specific geometric properties?
- How can we combine

  a) Reasons of similarity in Figures

  b) Transformations and symmetries

  c) Geometric patterns

  d) Mosaics & paving

  e) Tessellations
- How can we be inspired by the art for making artistic creations and constructions? Why does the beauty of a work of art emerge through the science of mathematics?
  (Argyri, 2018)

The novelty of projects implemented in the syllabus of high school as a distinct section of the curriculum, is based on the systematic involvement of the educational principles of exploratory learning, interdisciplinary knowledge domains binding to group cooperation and organization of students. (see "Innovation of Research Operations at the High School" , which is available in the website of the digital school, http://digitalschool.minedu.gov.gr). Students as young "intellectuals", "scientists" and "researchers" cooperate closely in the context of initiatives and options through their experience, they approach the new school knowledge in different ways through questions, experiments and investigations which refer in science. This is an important educational innovation, based on modern and applied pedagogical principles and aims to enhance the educational role of school to connect knowledge with reality (Matsagouras H. 2009: p.28 cited in Argyri, Lalazisi, C., 2014).

The teacher-centered teaching of mathematical concepts in combination with the fragmentation of the syllabus of Maths into chapters usually gives students the impression that Maths is not related to the real world, resulting in negative attitudes and perceptions.

4.2 Student needs addressed

The principles of learning and teaching assume exist, on the condition that:

a) Learning requires active and constructive participation of the student in activities that demand efficient and flexible strategies and in addition, they help them understand and think logically in activities which set their own learning goals and help them correct their mistakes (Argyri, P., 2014).

b) New knowledge is constructed better when associated with pre-existing knowledge and organized through the effective understanding and not through memorizing.

We rely on the basic pedagogical and didactic principle according to which learning is better when incentives and interest are created in learning and in the context of innovative teaching approaches dictated by the curriculum chosen as the subject matter of the project examining the relationship between mathematics and art

Therefore, students develop research thinking and skills, as they try to search for data, to develop possible connections and research questions, to identify common facts that help them to build bridges between ancient and modern Greece and between Art and Mathematics.

Students also combine their facts and their data on a personal way, so these activities help students to express their own way of thinking and support their acts with arguments. The co- creation engages them in meaningful activities, in which they will collaborate and negotiate different ways of expressing themselves.

5. Learning Activities & Effective Learning Environments

Science topic: Geometry, Art (Relevance to national curriculum) Class information Year Group: 1st-3rd grade of Junior High school, 1st- 2nd grade of Senior High school Age range: 12-16 Sex: both Pupil Ability: mixed	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) laptop, digital tools, drawing tools, questionnaire and rubrics *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* *Classroom, technology lab, museum* *Health and Safety implications? none* *Technology? digital tools, computer, internet access* *Teacher support? scaffolding*
Prior pupil knowledge Students need to have some basic knowledge of mathematical notions.	

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Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will:

a)Answer research questions through dialogue

b) Make Bibliographical review to select facts and data:

The bibliographical review in **the Middle Age** and the Renaissance revealed aesthetics, harmony and beauty of painting and architecture beneath the strong influence of mathematical precision and geometrical thinking.

Gothic architecture and Islamic art have been strongly influenced of mathematics. Artists such as Leonardo da Vinci (1402-1519), Pierro della Francesca, Brunelleschi Filippo are known for their achievements both in science and in arts. Other ways of manifesting the relationship between mathematics and art have been examined through the study of gold phi number and its geometrical of structures and "roaming" in the wonderful world of Fractals.

The bibliographic journey closes in **modern art** with the works of Escher and Vasarely and the mirages and it illustrates that art aesthetic treads along with the logic of mathematics.

c) Use new technologies and properties of mathematics educational software (Sketchpad, geogebra): The use of new technologies for the creation of a modern digital art necessitates the exploitation of educational software properties for presentation, construction and testing of artistic constructions, which confirm the strong influence of mathematics in art. The potential of dynamic geometrical software have been exploited and students practice using and examining technological tools, creating artistic compositions, urging their creative imagination and artistic instinct at the same time.

The students have the opportunity to take the initiative and active role to reveal the interaction of mathematics and art.

d) Create artistic creations

e) Organize visits on Museums

Assessment Students artistic products	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* *These activities are grounded on students' special needs and interests. During the Inquiry Phase students develop scientific thinking but also act according to their skills, needs and interests.*	**Key Concepts and Terminology** **Science terminology: Geometry** **Arts terminology: architectural creations, monuments, paintings, mosaics**
Session Objectives: During this scenario, students will anewer research questions, make Bibliographical review, use new technologies and properties of mathematics educational software and create artistic creations.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	**Progress and Preparation** Students are engaged with teacher's questions. The students were divided into groups and answered individual research questions. In every encounter through dialogue, exchange of views and arguments, they testified their own ideas about the interaction of mathematics and art.	Teacher uses challenging questions and the web (images, videos) to attract the students' interest in ancient Art and Mathematical thinking.	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	**Bibliographical review** Students investigate on mathematical notions. The student groups are coordinated for a bibliographic search of information in the school library, internet, scientific articles and journals. **Team A:** They dealt with the relationship between mathematics and art in the Middle Ages-Renaissance. **Team B:** They dealt with the gold ratio (φ) and the world of fractals. **Team C:** They dealt with the Modern art. Students collect a lot of pictorial material that was to be analyzed and justified through the development of discussion forming arguments, exchanging opinions. Moreover, they	The teacher follows and watches the whole procedure and identifies possible misconceptions.	

		present their bibliographical material in the plenary of the class.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students try to find combinations between mathematical thinking and artistic creations. They discuss between	Teacher promotes dialogical procedure and acts as a facilitator of the process.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students discuss about possible ways of representing their findings and decide which of their explanations are scientific.	Teacher promotes dialogical procedure and acts as a facilitator of the process.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	**Using new technologies and properties of mathematics educational software (Sketchpad, geogebra)** Using new technologies and educational software of	Teacher encourages the whole procedure.	**Paintings, drawings, wallpapers, tessellations on computer**

		Maths (Sketchpad, geogebra) according to the necessary bibliography and guidance.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	**Educational visits** The tour in the world of mathematics in context with the wonderful world of art was completed with experiential activities of students during their educational visits. In the educational program of the Museum Irakleidon (http://www.herakleidon-art.gr/el/), which was attended by students, the points where both areas of human thought and expression meet and interact were detected. Emphasizing the geometric period of Greek art, the relationship of Mathematics and Music (Pythagorean scale), the classical art	Teacher helps students to make stronger connections between art and maths.	

		(Parthenon-Proportions-Golden Section), the linear term (Renaissance), the geometry of modern art (Cubism) and finally the modern one called "mathematical art" and self-similarity (fractals). Finally thanks to some appropriately selected works of MC V. Vasarely and Escher and other artists, students discover and examine the nature and philosophy of important mathematical concepts. In addition the educational visit to the National Institute of Sciences (http://www.eduscience.gr/) mobilized the interest of students with specific scientific constructions and exhibits which are related with concepts and knowledge about the interaction of mathematics and art. Through their		

		interaction with them, the students participate in a dialogue of deeper research and understanding		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	**Create artistic creations** Students create geometrical constructions with specific geometric properties: Reasons of similarity in shapes, transformations and symmetries, geometrical patterns, mosaics and paving (See: Creativity, efficiency and artistic skills of the students are depicted in original manufactures and handicrafts. The sense of beauty and harmony of proportions are cultivated with the opportunities given to students to create geometrical synthesis promoting their creative ability and imagination	Teacher balances the outcomes of the creative educational process.	**geometrical constructions** **shapes, transformations and symmetries, geometrical patterns, mosaics and paving**

		fabricating decorative patterns using well known geometrical shapes and exploiting their geometrical knowledge.		

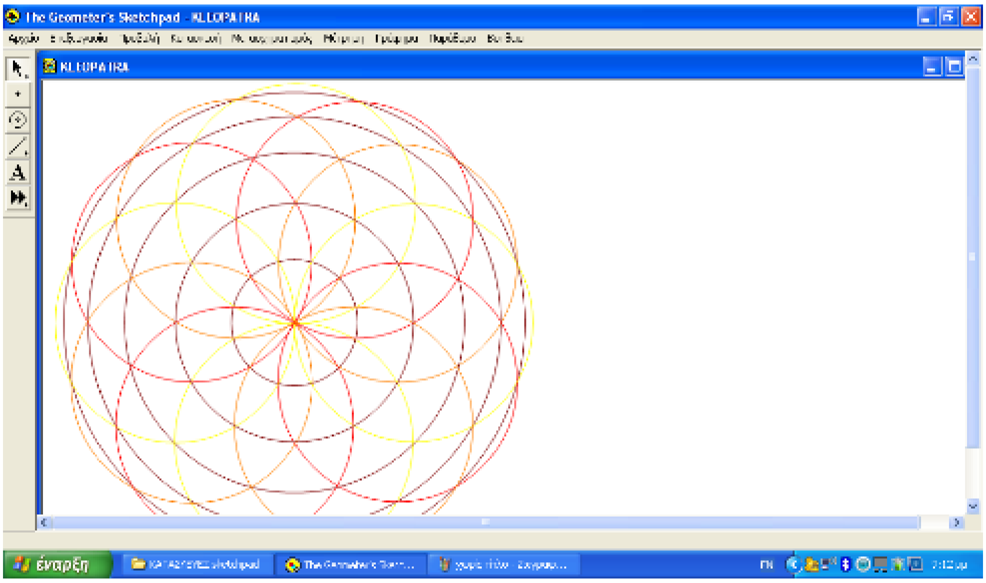
6. Additional Information

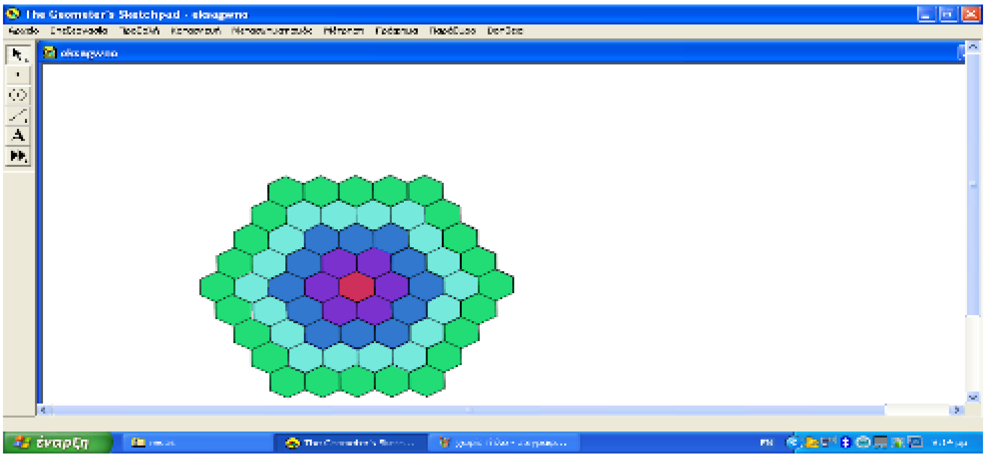
It is important to give students an opportunity to explore the ways in which the interaction of Maths and art take place throughout centuries. Art and Maths constitute two of the primary human activities. We have found artifacts (representations on walls of caves, stones, shells and later in more complex structures such as juvenilia jewelry, amulets, etc.) since the dawn of the human civilization. The first mathematical concepts of measurement, calculating distances or sizes are imprinted in primitive forms in samples of settlements dating from 2500 B.C. They are different semiotic systems, but as the embrace of Arts and Science can affect and strengthen the scientific meaning in today's society, the question "how the students can acquire scientific notions working in different semiotic systems" is really still interesting. Moreover, modern learning theories attach great importance to the social-cultural factor and play an important role concerning the organization of courses that favor social interaction and collaborative, group learning (Argyri,2018, 2014, 2013).

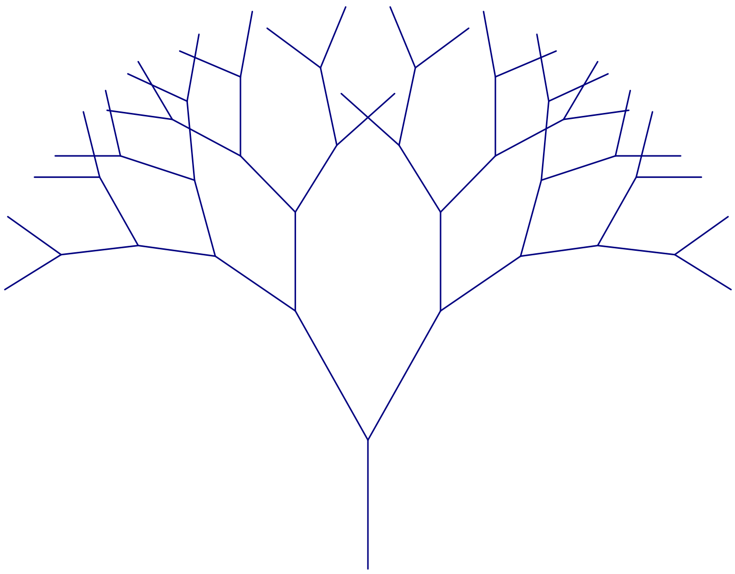
Research studies show that the combination of interscience and teamwork of the projects raise pupils' interest and improves their attitudes, their self-esteem as well as their skills for cooperation and, by extension, learning and knowledge retention (Rogoff et al. 1998, Prince, 2004: Joyce, Weil and Calhoun, 2008 cited in Argyri, Lalazisi, C., 2014).

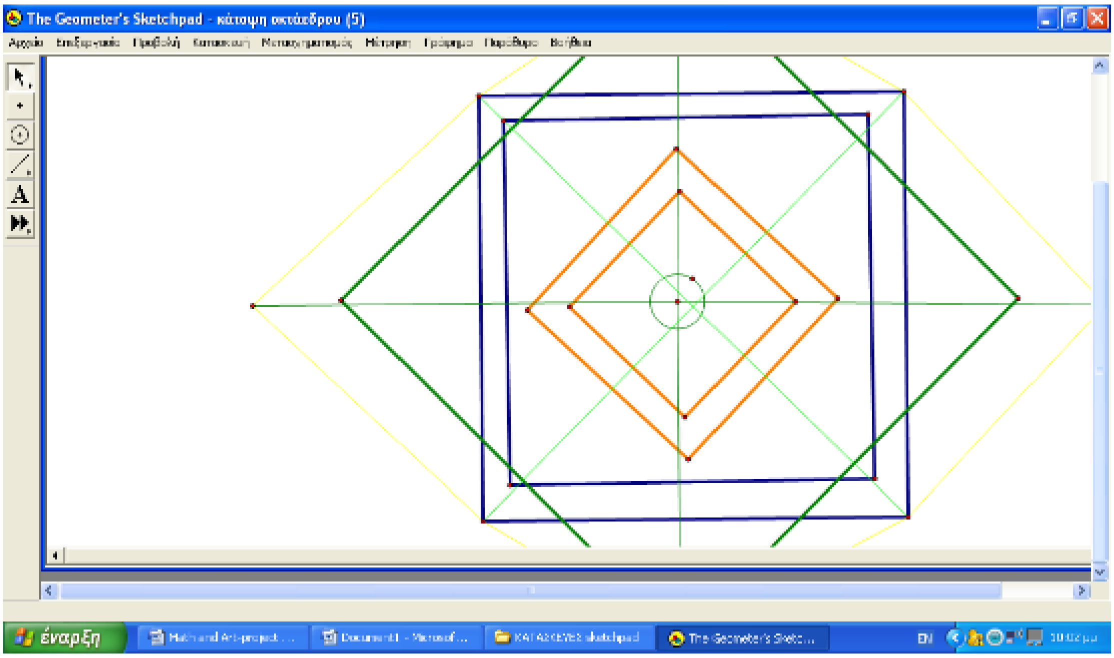
Some of students' creations are:

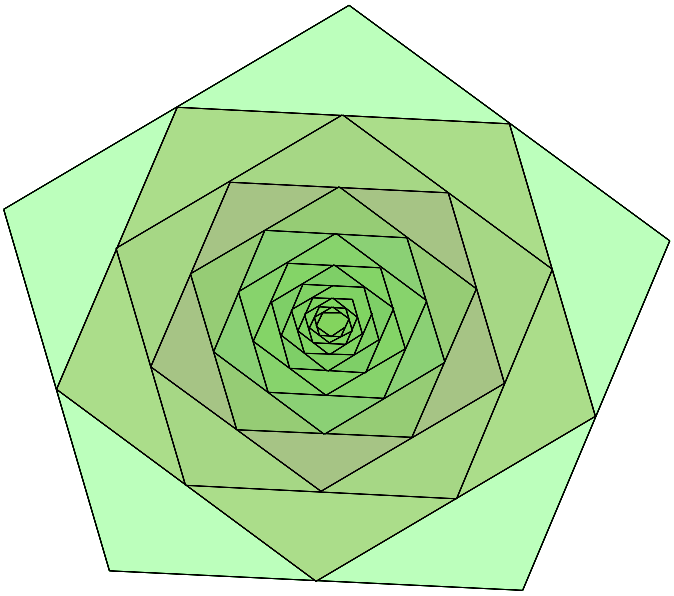
APPENDIX A



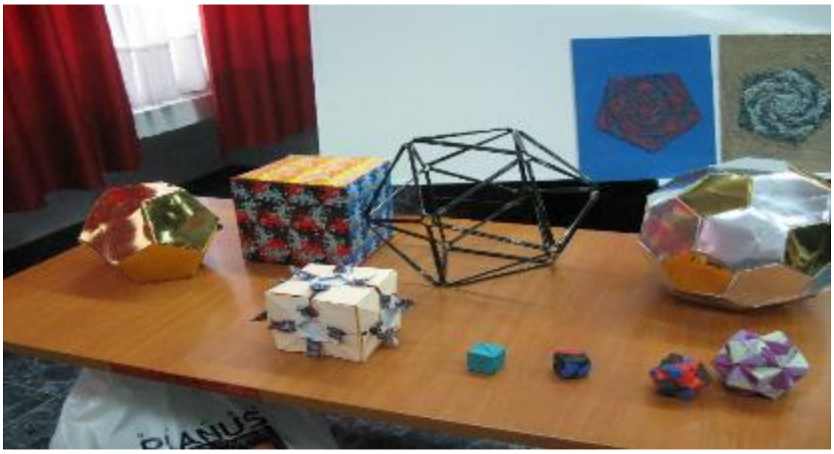


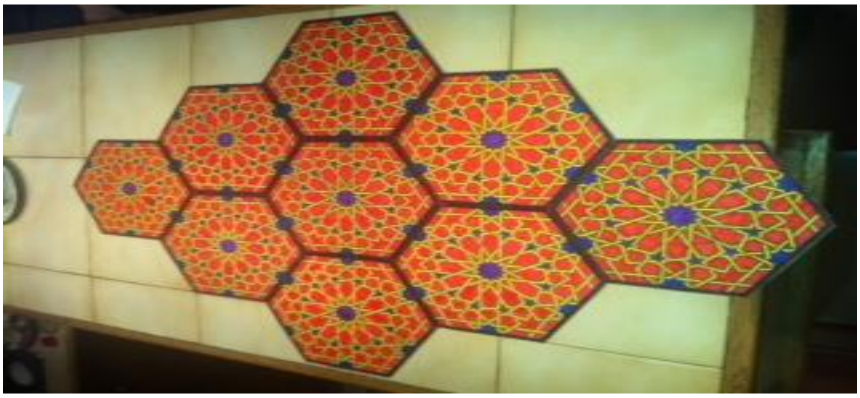


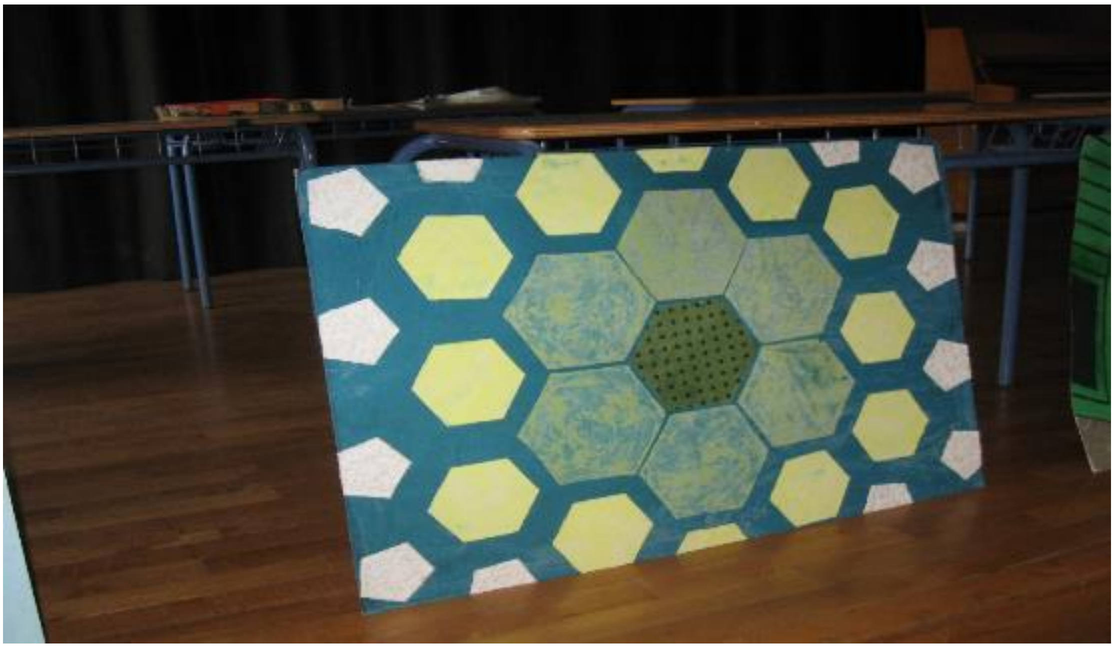


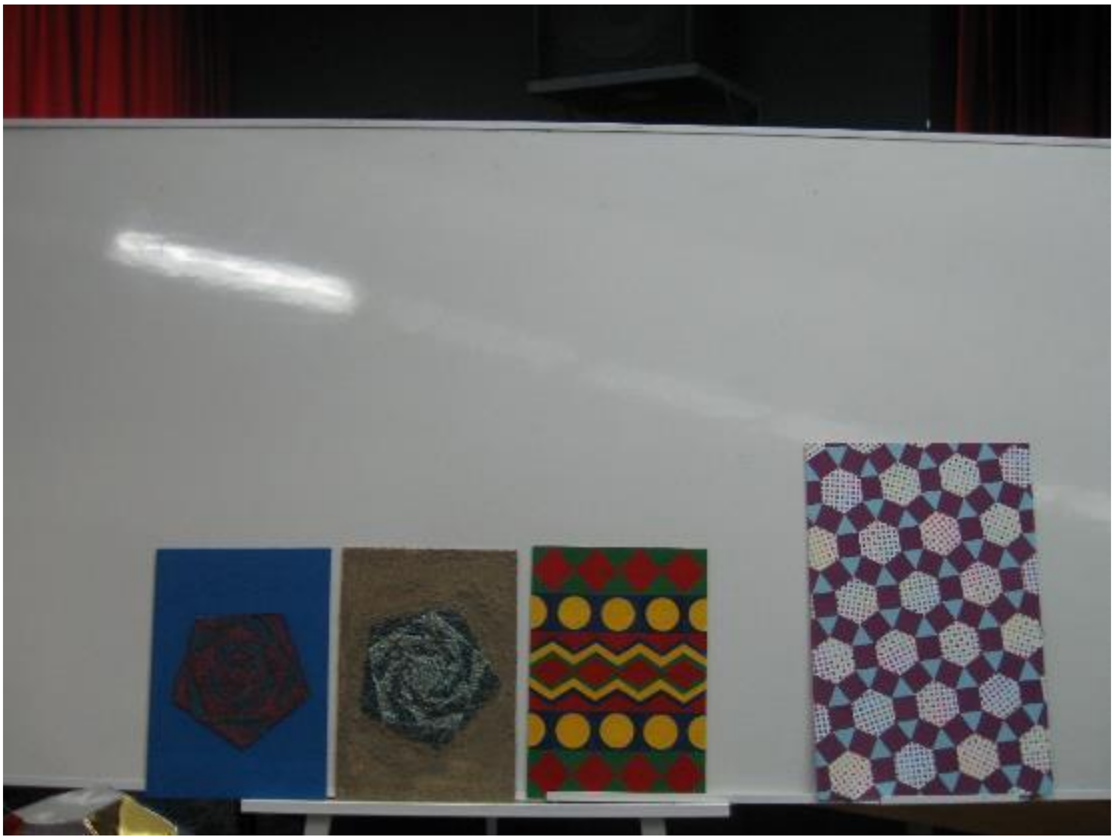


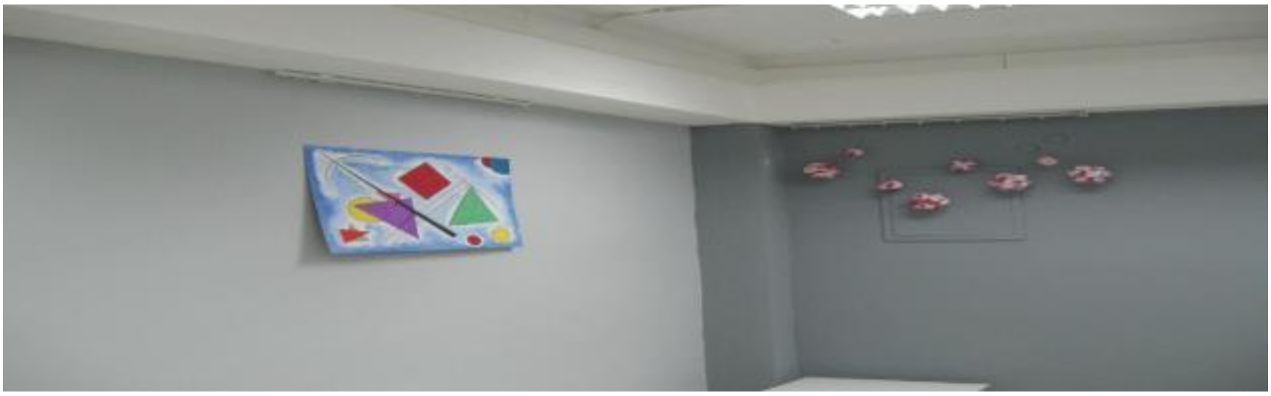
Create artistic creations











7. Assessment

For quantitative assessment we recommend the use of the "Science Motivation Questionnaire II (SMQ-II) ' 2 (Glynn, et.al, 2011; maximiliane, Schumm, Bogner, 2016) that is addressed to students.

The results of the project will collected through questionnaires to pupils' quantitative and qualitative data during and after implementation. The quantitative and the qualitative analysis at first phase showed that, during the didactic application developed positive beliefs and mobilized the students' interest in mathematics and art, created an incentive for deeper understanding of the subject of geometry and understood sufficiently geometry fractals. Creative-critical thinking skills were developed as well as mathematics software for designing complex geometric structures. The positive attitude is explicitly stated in semi structured interviews.

A)The bibliographical search considered interesting by the students and achieved the intended objectives of knowledge: Students' responses showed that they were informed about the following topics:

'The architecture and art in the Renaissance', ' painting in the Middle Ages', 'the works of Leonardo Da Vinci (.... I did not expect to hide so many things) ',' the relationship between art and mathematics in antiquity', 'historical data for the development of art which link everything around us ',' historical data for the development of art and ways of relating everything around us ',' the relationship of the golden section in art ',' appearance the golden section and the golden ratio in the natural world ',' fractal ',' information about the life and work of Escher '.

All students agreed that there was information that impressed the bibliographic presentation of all groups and gave them the impetus to deal with the backing of their study. The answers are: 'I liked the paintings of Esher and their analysis',' the golden ratio ',' creations of Escher ',' The evolution of art through time ',' the work of Renaissances , the analysis of the drawings was amazing ',' I liked very much the work of Escher and motivated me to look more ',' all groups showed significant projects equally interesting topics such as the golden section and art and math in Middle Ages ',' I particularly liked the presentation made for gold ratio φ'.

B) Issues mobilized interest and rated 'pleasant'.

Quantitative content analysis of open responses of students to questions was done: i) what has drawn the interest of the state of implementation of the project, at an intermediate stage of implementation ii) what surprisingly pleasant features and factors are acknowledged project, after the completion.

The following findings were found after encoding and processing of answers: The application of mathematics educational software in the course of implementation of the research fits the data are quite liked by the students. Some of the indicative answers reflected clearly that mathematics educational software have mobilized students' interest and an element of teaching practice that is very positively accepted: 'exploration Sketchpad', 'Sketchpad', ' I learned to design by mathematical software, application geogebra-Sketchpa' ,' worked with mathematical software'.

Also what is very important is that they great frequency growing skills is something unexpectedly pleasant. They state: 'experience', 'extend knowledge', 'knowledge about art and mathematics', 'we learned many things about the relationship between mathematics and art', new information, questions for discussion ',' how many things I could learn and eventually I did learned '' exchange of views'

C) The attitudes that the students formed towards the lesson of geometry is mainly reflected in the qualitative analysis of their responses in interviews. The content analysis of the interviews provides very important information about the contribution of the teaching course of the project in shaping perceptions and positive attitude in the course of geometry, in recognition of the important role of mathematics in everyday life.

They were asked to answer: 'In what way do you think this project has helped you with mathematics' ?

Student 1: "Through the theories that exist and you can see the geometry, these theories through action we can understand better"

He continues more specifically: "For example, when reading for geometry exam were theorems and definitions that helped me to understand very much through the experience I had with the project at project ... I understood the definition of mathematical more deeply"

Student 2: "Maths is actually what we have been told since old times that it interprets the world in another language"

Student 3: "Specifically, maths is a beautiful study, it has thought, it has a structure, but I like geometry much more ... I like it because now that we have combined it with art I have another view"

Student 4: "The goal of mathematics is to open your mind to think about new ideas, solves not only problems, but also helps in life ... If you do not succeed, this will find another way to solve something"

It is reflected that the project acted as a catalyst in the promotion of the role of mathematical science. But most importantly contributed to the understanding of the geometric theory through the connection of mathematics to art.

But assesses their instructional practices during the course of the project, when students said:

"Maybe it's the wrong way to approach mathematics are taught ... Through the project we learned to see other aspects of mathematics ... The project helped in the expansion, there could be other courses that would help in further expansion of mathematics »

"The teacher plays a very important role in what you see in front of you, what you teach and what you hear depends on how you will receive. That is when the teacher is super and you do not sit and read it will not work»

8. Possible Extension

Through this project students learn about scientific concepts by combining different domain areas, and by realising that a scientist use his/her knowledge to find solutions to everyday problems. By learning more evidence about a field and by cooperating with others we can realise what we learn. The combination of different ways of learning helps students to find their own interests and skills and feel useful. This project can be expanded on other domain areas, such as architecture.

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D3.2.36 Edutainment in everyday life

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1. Introduction / Demonstrator Identity

1.2 Subject Domain

Multi disciplinary – Physics, Chemistry, Biology, Mathematics, Astronomy (General STEM)

1.3 Type of Activity

The project is a school based activity and includes educational activities that promotes creativity and Inquiry-Based principles on schools. It is also includes potential visits to research centers and museums so it promotes school- research center collaboration. The activity is local.

1.4 Duration

This is typically a three- day activity.

1.5 Setting (formal / informal learning)

The setting is both formal (i.e. school) and informal (e.g. research center) and engages multiple actors such as science teachers, researchers and even parents.

1.6 Effective Learning Environment

- Communities of practice
- Arts-based
- Dialogic Space / argumentation
- Visits to research centers (virtual/physical)
- Communication of scientific ideas to audience

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2. Rational of the Activity / Educational Approach

2.1 Challenge

Nowadays school systems but also all the members of a school community face lots of challenges. These challenges are firstly relevant to the educational practices and the purposes of school education. One of the main problems of the most school systems, included the greek education system, is the students' lack of motivation. Nowadays students are not interested in STEM Education, as they think that science education is irrelevant to their lives. The majority of students cannot connect science education to their everyday lives. Moreover, they find teaching methods old or inappropriate for their acquisition of knowledge, as these are not creative and challenging. The problem of the distance between school knowledge and students' everyday needs is obvious, when students are not encouraged by the teachers to link their hobbies to educational practices or when the teachers focus on old, traditional educational methods, techniques and means.
In addition, although most school curriculums have managed to simplify scientific knowledge to school knowledge, they have failed to deal with modern scientific notions according to the global, new findings on science. Consequently, students cannot connect their knowledge to new findings on science and technology and as a result they are not able to develop a science literacy (Sandoval, 2003) and a scientific knowledge with disciplines. The difficult scientific notions acquire a different way of thinking and teaching, where modern pedagogical framework is taken into account and is adjusted to basic principles, such as the use of different cognitive semiotic systems of the representation of scientific knowledge.
Arts is an alternative semiotic system which can helps students to represent on various ways what they learn. If we, also, take into consideration that students have to learn to express their feelings in a demanding world with lots of difficulties, we can realize that a combination of Art and Science can help students to express themselves on different levels. However, Greek educational system is focused on academic skills and does not promote art and artistic dimensions.
The lack of scientific literacy means that students do not make their own decisions about science and social issues and they have not the appropriate skills to interact between social and personal dimensions. On 21st century, this problem is really crucial as it means that students are not interested in nowadays societal challenges but they also may not have the appropriate skills to do so. Greek students cannot build explanations and justify their thesis about nowadays problems and creative ideas could help them to these directions (Smyrnaiou et all, 2017).

2.2 Added Value

Edutainment on everyday life is a CREATIONS initiative that is designed as a transversal meeting point between students' hobbies and modern pedagogical theories and frameworks expressing Creativity and an Inquiry-Based Science Education model. Edutainment is a new concept in education with the aim to educate students through entertainment. Edutainment is a derived word that states a mixture of entertainment and education or marriage of education with entertainment. (Colace, et. al., 2006) The main purpose of this application is to support education with entertainment. The first point of this procedure is to take into consideration students' interests and hobbies, as school is thought as a play. Music and video are used to teach subject domains, such as Maths, Science etc. as well as motion pictures, films, documentaries and games. All types of games, including board, card, and video games, may be used in an educational environment.

Lots of different descriptions of edutainment were made by many researchers. Edutainment is defined as to encourage entertaining learning with the way of interaction and communication, exploring by creating learning awareness, trial and error (Shulman and Bowen 2001). Colace et. All (2006) describe this approach as a type of entertaining which is designed with the aim of educate by including entertaining variety such as multimedia software, internet sites, music, films, video and computer games and TV programs in order to exhilarate in addition to educate. Also, for Buckingham and Scanlon (2001) "Edutainment is named as a hybrid type which is based on visualizing and animation made with the formats like game, diegetic things and visual materials."

Dramatization, story simulation, edutainment in computer environment, video based- learning, films, cards, puzzles, robotics etc. belong to edutainment activities. Especially, computer games are increasingly

becoming the topic of serious research. They are strengthening as a mainstream entertainment activity, as the increased general interest in computer games research is rubbing off on educational computer games research. Edutainment titles are characterized by using conventional learning theories providing a game experience, relying on simply gameplay and are mostly produced with a reference to a curriculum. The most important focal point of the framework is the ability of computer games to offer concrete experiences providing relevance and engagement leading to students' investment in the learning activity.

As a result, students use their hobbies and their interests so as to acquire new knowledge. They also learn to express their ideas and feelings. The learning concept is based both on students' individual development in learning environments but also in a cooperative way. Having a good time, students use resources and methods regarding their hobbies to create and combine different subject domains.

Therefore, Entertainment and interaction which is thought missing in education, attract learners' attention because of being in nature of game and increase learners' excitement and enthusiasm to teach students any subject and information that is hard to learn. Students learn how to apply their own knowledge and understand or internalize what they learn.

Moreover, this approach provides learners' having a good time with the way of creating and experiencing. Games can also be used for teaching sustainable development as they increase players' understanding of issues around sustainability (Katsaliaki, et, all.2015) and have enhanced their knowledge of sustainable development strategies. Our classification of the games' characteristics assists educational instructors and potential learners in identifying games that are best suited for their teaching and learning needs. Technological Pedagogical Knowledge (TPC), which refers to the development of skills deriving from the effective integration of technology in the teaching practice (Smynraiou et all. 2016). Moreover, modeling can play a role in the learning process when we ask students to construct models (Smyrnaiou et all. 2007).

If the aim is to teach new things to the next generation and to provide permanence of the teaching, teaching methods should be ordered in the direction of their needs and wishes.

3. Learning Objectives

3.1 Domain specific objectives

The Edutainment on everyday life Initiative's domain specific objectives are to:

- help students to search for scientific data to fully represent a scientific phenomena
- help students realize and explain the scientific phenomena
- help students represent scientific phenomena
- help students link scientific knowledge to their everyday lives
- Get students interested in science and research through multiple tasks, such as games, videos, photography etc.
- Initiate contact between students and other professionals (for example researchers)
- Bring schools closer to local community
- Engage parents and the general public into schools' happenings and events
- Open the school to the community and involve all the stakeholders by encouraging contact of students with other professionals such as photographers and science communicators (such as photographers, artists etc)

3.2 General skills objectives

In the context of the Edutainment on everyday life, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Acquiring creative skills and training
- Scientific interconnection of science with aspects of art (students will create multi-disciplinary art activities- which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- Make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.
- Develop spirit of cooperation and teamwork
- Connect the science classroom with professionals, parents and local communities

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to high school students to combine their hobbies to scientific concepts and knowledge from the material being taught in schools. In this way, students learn science in a creative way. It follows a scientific approach while opening doors to experiencing new possibilities on several levels.

As "teaching the students according to what they know" is one of the main pedagogical principles, students and teachers select a science theme that would like to develop and students are asked to discuss and collect data about different scientific phenomena. Students and groups can choose the science field (physics, chemistry, mathematics, biology etc.) that is included in their curriculum. The number of students that can participate is not fixed. The activity can take place as part of the 'project' course of the curriculum (e.g. in Greek schools) or as part of the regular activities of school within the classroom.

Students can take different photographs, make their own videos or to create their own games for the representation of scientific phenomena or of the same scientific phenomenon. In this way, it is given the opportunity to students to inquire about scientific concepts and issues of their interest and express their findings in creative ways. School exhibitions, competitions, online galleries, museum presentations and articles to the local press could be the way to communicate the project and science topics to the general public through this approach.

This demonstrator supports teachers with ideas about how they might incorporate inquiry- guided approach into their everyday classroom teaching. In the process the teachers should try to adopt an inquiry based approach that will lead to better understanding and interpretation of each topic. Furthermore, teachers are supported in both the pedagogical part of the initiative. The support to teachers and students is provided through visits to schools, online meetings and special workshops. Students are also provided with open access to research centers in order to use up-to-date information of science and communicate with researchers.

In most cases of course school science continues to be taught as the transmission of a series of unchanging facts from teacher to students, with students being required to learn these facts by heart. The notion that science should be taught in ways that stimulate their thinking and creativity has been supported by many educators and is the spirit of the current project and all its facets. Science must be appreciated as a set of subjects whose laws and concepts are continuously under challenge in both research and teaching.

Students engage in Possibility Thinking (PT) regarding how the creative artistic process can act as a base for deeper inquiry as well as an aesthetic medium of communication of the various hypotheses and evidence-based conclusions. The complete activity, within both science and art, is based on students' creation and observation skills.

In general this demonstrator aims at the enhancement of the students' cognitive involvement, their representation of scientific content using their cognitive processes, their emotional involvement, the social interaction and communication between them, the use of past experiences and the creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors, their brain, body and emotion coordination and finally the holistic use of their personality and their motives.

4.2 Student needs addressed

Through this demonstrator students will acquire new knowledge on different levels. As far as cognitive development concerned, students will build knowledge about scientific concepts from the curriculum of their courses. They will also learn to recognize the main keys of scientific notions to the everyday phenomena and they will link their knowledge to everyday needs.

Students will also learn to negotiate their ideas with others. They will learn to make dialogue with other students about the photography representations and they will develop critical thinking. As they will cooperate with other students, they will learn to build explanations and justify their choices. Through this procedure, students will identify scientific issues, make questions, collect data, explain and communicate their thinking

and the final conclusions. This transformation of initial ideas into grounded concepts helps them to become acquainted with the concept of learning science creatively through artistic activities. This procedure makes the whole educational community to realize that there is not a way of teaching and learning and students cannot only learn on as school environment but also outside the schools.

5. Learning Activities & Effective Learning Environments

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Science topic: STEM, Mathematics, Physics, Chemistry, Biology, Astronomy (Relevance to national curriculum, Greek Junior and High School Curriculum) Class information Year Group: 1st-3rd grade high school and 1st- 2nd grade of Senior High School Age range: 12 - 18 Sex: both Pupil Ability: Mixed	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Digital Cameras including mobile phone cameras** **Computer with Word processor (for accompanying text)** **Internet (to search for information and online connection with various digital galleries)** **Photo editing software.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The preparation activities will take place mostly in the classroom but also in Research Infrastructures (Virtual visits in CERN, National Center for Scientific Research "Demokritos"). Students will visit places outside the classrooms, for example on their neighborhoods. A place of final event such as Exhibition or Science presentation can be a research center, a city hall etc. *Health and Safety implications? A teacher guides and helps students during their activities.* *Technology? Computer and internet access, an online platform to facilitate communication with professionals, students' blogs to compare their photographs, video cameras or mobile phones, Photography editing software* *Teacher support? scaffolding*

Prior pupil knowledge		
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this activity, students will - **use videos, short films, photographs, music to the representation of scientific notions** - **discuss about scientific phenomena, be attracted to engage with scientific topics. They collect their data and search for relevant and scientific information about their topic** - **combine different semiotic systems for meaning generation. They acquire e deeper understanding of the topics. They make a plan of how they take the photographs and which criteria they have to follow.** - **contact with professionals (photographers, researchers, artists) to discuss about the topic and its representation** - **connect the characteristics of notions to each picture** - **explain their choices and justify if their representations are correct or not** - **work creatively, combining science to art. Combining science and art is a powerful and effective way of communicating the former as students can learn new things about various topics easier while having a pleasant time.** - **make posters with all the photographs, present their films, videos, songs and communicate their efforts to audience by exhibitions of their arts.**		
Assessment	**Differentiation**	**Key Concepts and Terminology**

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Students are engaged in work-group assessment processes throughout the preparation including the criteria of the photographs. **SMQ Questionnaires**	*How can the activities be adapted to the needs of individual pupils?* Activities are grounded on the respect for students' needs and interests as a cornerstone for its successful realization. The selection of the topic to be represented and the exploration of relevant issues depend on students. During the inquiry phase all students will participate and contribute with relevant to their interest data.	**Science terminology: Maths, Geometry, Physics, astronomy, Chemistry** **Arts terminology:** **photographs, video editing, drawing, digital models etc.**
Session Objectives: During this scenario, students will deepen their understanding on scientific notions, using their creativity and imagination and by using an everyday technique, the photographs.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions. Watch videos and use the web to explore scientific phenomena. Students discuss about these phenomena and search for images/ photos, paintings of notions.	Will use challenging questions and the web (images, videos) to attract the students' interest. The teacher specifies the topic, which can be part of the curriculum. The fundamentals of science/physics regarding the topic are discussed.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and*	Students look for examples of science and art representations to understand this	Teacher shows example of science and art representation to the students and discuss which one	

	play is crucial in *empowering* pupils to generate, question and discuss evidence.	transformation for one symbolic system to another.	notion from STEM will be collected for them. They can make some experiments with students acting like scientists.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will conclude to some pictures/ photos of scientific notions. After the discussion between them, they will have to match the characteristics of the notion to the picture they have collected. Students search for pictures, photographs etc of the notion given. They can	Teacher will also give specific pictures of scientific notions.	

		search to the internet base, to blogs or to other communities of practice in order to discuss and compare their choice. A visit to a research centre or a virtual visit to CERN can be programmed.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain their thoughts about art activities.	Teacher helps the students to understand the power Art.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students try to make their own art atcivites representing everyday objects relatively to	Teacher selects a scientific notion and ask for students to find photographs and pictures of this notion.	**Students make 3D models, constructions with everyday materials, structure**

				buildings, 3D geometric shapes, handicrafts, rotational symmetry art activities. For example students use the Pythagorean theorem to explore and measure topography in 2D/3D space.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students are called to present their findings and activities to the audience. They also can write a text in order to communicate their thinking to the	Teacher balances the outcomes of the creative educational process with assessment	

		audience in the exhibition.	features of the curriculum.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	All the school community organizes an exhibition and students discuss if their representations transfer successfully the scientific notions.		**Art exhibition**

6. Additional Information

During the students' preparation phase, all participants can be supported by professionals in the field of science and art. If necessary, visits of the organisers to the schools during the project are organized, in order to help and advice teachers and students during the development and preparation periods. Moreover, the CREATIONS Portal (http://portal.opendiscoveryspace.eu/en/creations) is an online platform where teachers and students have the opportunity to share their opinions and their educational resources and create their own communities.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of this Demonstrator.

For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)' (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

8. Possible Extension

This demonstrator can also be extended to various science topics and parts of the curriculum. Edutainment on everyday life covers a range of themes and as a result, students can expand photography techniques wherever they want. They can also combine it with other forms of arts, such as painting or even other cognitive subjects, for exampling by writing a short story next to their photographs. By encouraging teachers and students from all over the Greece, and even remoted areas, it could be become a large scale national activity, where students capture the reality according to their personal needs and the culture they are grown up and they communicate and share their creative ideas and their own cultural elements.

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.37 GSOrt (Global Science Opera in real time)

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Petros Stergiopoulos, Ellinogermaniki Agogi
Code:	D 3.2.37	**Contributors:**	
Version & Date:	**V1.0, 27/05/2016**	**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Mathematics

1.2 Type of Activity

Performance

1.3 Duration

3-6 months

1.4 Setting (formal / informal learning)

- School Based with ICT & teleconference support
- School- Art@CMS / CERN collaboration

1.5 Effective Learning Environment

Communities of practice (both web-based & physical)

Arts-based

Communication of scientific ideas to audience

Dialogic space/argumentation (school based)

2. Rational of the Activity / Educational Approach

2.1 Challenge

To approach scientific concepts through performance arts and body-motivating activities.

The objective is to produce an online live (or recorded) interactive, audiovisual, artistic event with multiple distant schools linked together via videoconference. A GSOrt event is the result of collaborative preparation, co-creation and realization of a live-performance sympraxis, with an emphasis in Music.

The GSOrt demonstrator will also have the task of initializing educational communities into the idea of "sonification" for educational purposes that is the challenge of explaining a scientific concept through sound.

The approach that the demonstrator adapts towards this task is threefold.

- Symbolic (the connection between sounds/music in comparison with the scientific concept is purely artistic)
- Mathematic (the connection between science and the Arts is directly reflected in pure mathematics)
- Adaptive (which is a combination of the above)

The symbolic way of sonification in an educational setting we can say that fully rely on the creativity of teachers who encourage students to approach imaginative ways to convert ideas into sounds. Using basic concepts of the musical phenomenon as pitch (or even noise),notes (tone frequencies), note durations, Time signature (or other rhythmic or measure attributes), teachers guide the students to create sound designs, or musical pieces, expressing the required concepts.

The mathematical approach is associated with the direct sonification of data. Here the teacher explains the correlations between arithmetic or mathematical figures and the behavior of data flow (the parameters) of a scientific concept. Usually this method employs mathematical applications that can be associated with live coding, giving data conversions to audio directly via a computer application.

The adaptive approach is the combination of the two above methods. In the adaptive approach the teacher has the opportunity to choose how sonification can assist him/her depending both on the teaching needs and the learning environment. In this way purely mathematical approaches can be combined with creative solutions coming directly from a performance arts setting.

2.2 Added Value

Developing a network of teachers online channels sharing multicast-activities inspired by science on national or international level through the "Let Us Share The Music" practice.

"Let Us Share The Music" is a multiple-site-link scenario in which all participants (remote sites) collaborate with each other in order to create and perform a music web event. "Let Us Share The Music" was the title of the demonstration-scenario that was carried out successfully during the 5th Educational Conference "School of Tomorrow (http://www.ea.gr/ep/schooloftomorrow/main.html).The scenario of this action is selected and registered as "good-practice" by the Greek Pedagogical Institute as part of the Major Teacher's Traning Programm.

Working in parallel to this approach, the demonstrator aims to enhance special music tuition from a distance to places where music education is scarce or impossible. Workshop is addressed to teachers with prior experience in multiple-site videoconferences who are interested in hosting cultural events prepared by remote educational communities.

3. Learning Objectives

3.1 Domain specific objectives

GSOrt demonstrator aims to produce an advanced interactive scene of the Global Science Opera. The main objective is to motivate rural and remote schools to collaborate in all aspects of the development according to the GSO guidelines (developing sound contributions, stage performances, sets, music sound/music recordings, dialogues etc). Remote schools collaborate through online videoconference. Teachers develop materials that are part of the sequence of screens whch form the final scene.

Teachers produce an outline of the characteristics of the web event including the introduction of the participants, the goals, the nature of the event and the main aspects of interaction are compiled by the organizer. All participant-sites, or their main representatives (Alpha contacts), are invited to agree or adapt this outline according to their fundamental educational needs. Actual broadcasting venues or rooms involved in the multicast are defined and examined. A time schedule is arranged with milestones and objectives for all the rest of the phases according to WASO or ST case studies.

3.2 General skills objectives

-To understand scientific concepts through body-motivating activities.

-To understand scientific concepts through the sonification of the details needed to describe them

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to motivate remote schools to collaborate through video-conference in order to produce audiovisual and performance-practice content for the development of a Global Science Opera Scene. The main aim is to engage rural schools in this process in national or international level.

4.2 Student needs addressed

Students collaborate in teams in order to produce audiovisual content that is directly related to the Global Science Opera libretto. The audiovisual content is put together in order to form the corresponding scene of the Opera

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics (Relevance to national curriculum) Primary and Secondary Education Class information Year Group: 4-6 grade Primary, 1st – 3rd grade of Junior high school and 1st-2nd grade of Senior High School Age range: 10-16 Sex: both Pupil Ability: mixed (The scenario allows space for pupils of various abilities to participate). Pupils with music background in secondary levels are encouraged to produce material or participate in activities that motivate their fellow students.	Materials and Resources *Optional material: musical instruments, percussion, drawing material.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Activities are open to take place any where that the teacher wants. School theatres are preferred. Video or sound recordings can be done inside or outside the classroom. The final performance (either for filming or live purposes) can take place in the school theatre.* *Health and Safety implications? none* *Technology? Computer with external webcamera. External microphone. Internet Connection. Handycam.* *Teacher support? scaffolding*
Prior pupil knowledge Though not necessary: pupils with music background in secondary levels are encouraged to produce material or participate in activities that motivate their fellow students.	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will: (Numbers of sessions correspond to videoconference meetings with teachers or students or both). **(1-5 sessions)**	

Be introduced in the idea of sharing an interactive sequence of events with remote participants. Scientific awareness is not only a matter of discussion within a classroom but also an engaging activity that can be shared between multiple student-communities. **(1-3 sessions)** **Be introduced into the planning of a distributed event the same way scientists exchange knowledge without boundaries. Part of one's team preparation or solving a quest bringing a scientific element to light, is cruscial not only for the people who produce it but also for any another team far away. Sharing knowledge through a collaborative activity could be a result of collaboration between scientifically aware members of a community the very same way as performers share stage or music.** **(1-7 sessions)** **Be introduced into the idea of using a performance experiment as an inspiring activity for gaining scientific knowledge. The steps for making a performance "sympraxis" are similar to the steps that guide scientists toward knowledge** **(1-2 sessions)** **Understand that scientific concepts are proved as evidence of human knowledge available to the human kind. This kind of unique sharing is needed and awarded by the society much like people cherish the arts as part of being human. The reflection of a scientific achievement upon all people is open and free to be criticized. Scientists build and evolve ideas and concepts in similar way artists depend upon the previous knowledge and cultural heritage in order to go further.**		
Assessment	**Differentiation**	**Key Concepts and Terminology**

Students enhance their creativity by putting scientific knowledge within the concept of Music and Visual performance.	*How can the activities be adapted to the needs of individual pupils?* GSOrt demonstrator is developed upon the idea of bottom-up initiative where rural and remote schools play the cruscial role in sharing student-centered activities outside region-boundaries. The needs of remote school are put in front.	**Science terminology: Mathematics, Particle physics, Particle detectors.** **Arts terminology: Music, Stage performance, Sonification, Interactive performance, Paintings, Libretto, Operatic scenes, Operatic Recitativo.**

Session Objectives: During this scenario, students will
Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by	**Students are introduced to the idea of participating in an online interactive event with distant communities. The**	Teachers prepare a draft of the interactive scene by mutually agree on their roles of performance and contribution. This includes a summary of the	**Drafting upon the main characteristics of the event such as stage sets, costumes, movements,**

	interdisciplinarity and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	**theme of the scene along with the roles of each site, combined with the corresponding educational needs and target group, are taken in account in order for the teachers to introduce IBSE**	scene, the characters, and the distribution of action among the participants according to the needs. Preparation of material (such as sets, costumes, scene-pictures, videos, sounds, music, etc) is defined during this phase and arranged according to time-schedule.	**voices, musical motivos,**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	**Active Investigation. (Script/directing group: Investigate characters and generate ideas for dialogues/actions,**		**Actor group: Investigate characters and work on performance in collaboration with script/directing group, Music group: Generate musical ideas**

				which correspond to the script, Dance group: After consulting with script/directing, actor and music groups, generate choreography ideas to incorporate in the play, Set/costumes group: Generate ideas after consulting script group and collect materials, Video group: Generate ideas after consulting script group and collect or create video clips.)

				This phase may also allow the use of the teleconference "virtual stage" as shared environment between sites if necessary.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	**Students are assigned the preparation of the scene-content and the local rehearsals, according to the above phase. They create an environment of inquiry based learning through the analysis of the scientific ant artistic elements given. Each role or dramatized collaboration**	**Teachers guide the students in gathering the necessary evidence and write about their characteristics.**	**Students experiment with sounds that can be used and recorded. The use of objects to produce sound is cruscial.**

		represents the common place of understanding between themselves, the scientific concept and the teachers. The virtual stage environment is available for online rehearsals if necessary.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	**Remote students are introduced online and perform their roles at the scene according to the Link Scenario.** **Students rehearse their activities after discussing about the content with their**	Teacher reads the explanations of students (or teams) in the classroom improving the concept according to science-teaching goals	**Remote teams are explaining particle motion through body and sound engagement. Recitativos, arias or plain crosstalk are the basic tools.**

		teachers. Direction and movement are settled.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students repeat their rehearsals.	Teacher help to find drama elements that support scientific knowledge. For this task they exploit movement, audio triggered activity or visual response.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	**Students discuss with their teacher elements of the other team's actions according to the scenario, and they ideas for improving their own roles/actions (or others') to support the scene.**	Teacher conducts the exploitation of possibilities either using discussion within the classroom or outdoor activities and stimuli such as virtual visits at CERN or dialogues with scientists.	**The event is video recorded.**

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students write down a sequence of activities needed to produce the scene.	**Teachers discuss with their students offline in seperate session. A collaboration-blog with the online material is built with potential open-discussion forum for further projects in the future.**	

6. Additional Information

Each member of the GSOrt community is encouraged to use teleconference GUI environment as a tool for online audiovisual performance practice. Video, pictures and audio material can be part of a sequence of screens that support the libretto. Virtual presentations support the flow of the scene based upon the mutually agreed sequence of events. Teachers are introduced in all possible kinds of interaction between the remote educational communities that contribute to the effort and the teleconference platform. GSOrt demonstrator uses an Adobe Connect Pro meeting room used as virtual stage. (“Dolphin” is the name used currently and "Skystage" is the name used by GSO). It is the virtual meeting point that serves as a "stage" in which both the virtual rehearsals and the final events take place. It is different from Skype and Google Hangouts in terms of screen manipulation and content management which is a feature that can be useful in this effort.

“Alpha contacts”-Hosts in GSOrt

A “host” of a videoconference meeting is considered an “Alpha contact” in the GSO community. GSOrt demonstrator aims to qualify Alpha contacts in running their own independent multicast channels that support interaction between multiple remote participants. Using Skystage as an Alpha contact can include more features than just activating Camera & Voice but this kind of usage will be determined for each one of the participants according to their technical capacities, availability and will.

All contributing communities have at least one teacher that represent them (similar to the Alpha contacts in GSO). Members are free to use Skystage in rehearsal mode whenever they want. Skystage can serve as a meeting point where you can exchange ideas, share word documents in double-zip (zip file containing another zip file with the document), share your screen, share jpeg, ppt, pdf, flv and mp3 with other Alphas in real time (the same way you do it in other teleconference platforms). Files can remain on Skystage for other Alphas to see and you can remove files you consider unnecessary. Skystage can be used freely anytime but, as the activity goes by, a timetable for scheduled rehearsals must be announced.

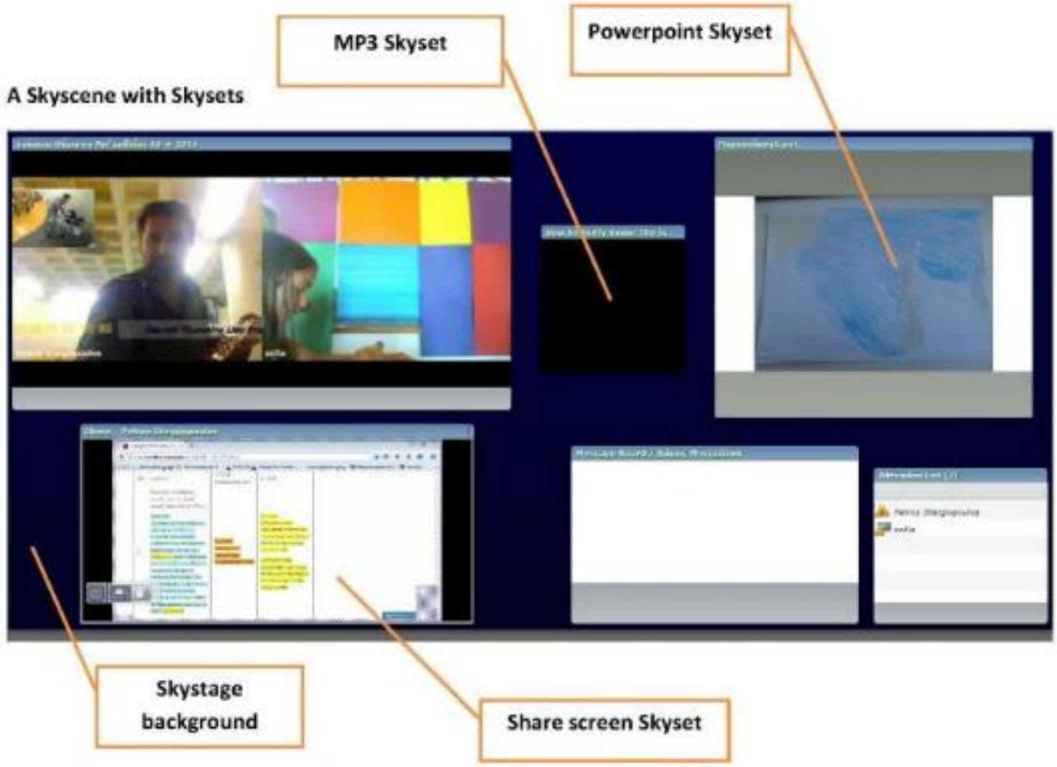
“Skysets”?

The virtual scenery of sets for Skystage are windows ("pods" is the right term but), let's call them "skysets". Apart from other virtual stage aspects, skysets can be classified in terms of bandwidth consumption from "light" to "heavy" as follows:

Chat (skyboard), Image, Voice, Powerpoint, Camera & Voice

(For “image” and “powerpoint” classification depends on the file size of course. Don’t forget that Skystage is a live broadcasting environment and files shared in the "share skyset" are distributed to all participants in real time. The lower file size the better).

As an Alpha contact you are able to use Skystage for performance from the moment you enter. You have the right - “by default”- of magnifying and restoring the size of skysets at will. This means that apart from being able to activate either your Camera & Voice, or just the voice from the Talk button below the screen, you are also able to use the maximize button of any skyset. If you click at the maximize button, skyset maximizes. If you click it again skyset restores itself to its prefixed size. This feature can personalize the participation of each Alpha on stage, especially when used on a powerpoint slide or an image. In this way interaction is not limited to the low resolution of the webcamera.



Skyset manipulation affects Skystage and all participants directly in real time. This means that what you see in your screen is what everybody sees in theirs. A skyset is responsive to all of us in real time so two Alphas must agree on its use just as if they were “touching” the same real object in the same real stage. So if you have one or more skysets (pods) in a layout (skyscene) then

every Alpha contact can maximize or restore them at will by default. That means that skyset manipulation is common to everybody by default. This feature, which affects skystage as a whole, is activated by default but can be deactivated from the skyset's settings.

Powerpoints as "skysets"

Each Alpha contact can upload a 1- 5 slide powerpoint with images (or words or links or all of them) to support or accompany the performance directly on Skystage. As a suggestion the powerpoint can show: images from the preparation of the event, an experiment related to the event, a link to a page, an image used as scenery, an image used as a reference to what we see and hear. The powerpoint skyset is used to support the scene prepared.

Videos as "skysets"

Skystage can support the live synchronized video performance, providing that all participants are linked with sufficient bandwidth. Final video skysets are submitted and uploaded on Skystage prior to a rehearsal. A combination of skysets is actual a screen-layout, let's call it: a "Skyscene"

Skystage is a multiple-screen-layout environment. Different compilations of skysets will be arranged in different layouts (screens as scenes), called "Skyscenes". This works just like preparing "scenes" on a play. A skyscene is a saved compilation of skysets including the "Camera and Voice", the "skyboard" and the "Powerpoint" skysets. Skyset-sizes are prefixed by host but they can change during the rehearsals.

Skystage will include two kinds of Skyscenes: draft and final

A draft skyscene is prepared for rehearsals. Except from the above skysets, a draft skyscene contains also an attendee list pod (so that everybody sees who is present) and a file share pod (for uploading and downloading material). Skystage is now on rehearsal mode so the skyscene which is now active is a draft skyscene. Skyset sizes can change upon request to the host and a draft skyscene is subject to change any time.

A final skyscene contains the fixed locked size of "Camera and Voice", the "skyboard", the "Powerpoint" skyset with its final .ppt content and any other skyset requested during rehearsals. Each country will have its own Final skyscene on Skystage.

The sequence of the final skyscenes is managed by the host according to a Link Scenario which is the sequence of skyscenes derived from the WASO libretto and the scenes of the Opera. It is useful for the hosts but it will also be useful for everyone who wants to understand the "skystage" activity or "technical" profile of the libretto.

Levels of interactivity

Depending on circumstances and capabillities the levels of interactivity describe three possible situations of interaction with skystage: High, Medium and Low. High and Medium levels are synchronous.

(1) High (synchronous)

Advanced interactivity includes a powerpoint or video presentation which will be broadcasted live assisting a live audiovisual event. The final version of the powerpoint presentation will be based upon the Skylight powerpoint protype and it will be uploaded to Skystage prior to the rehearsals. The ppt will be consisting of 5 or even more slides. These slides will serve as background or side-images of the main skyscene. A change of the dimensions or number of skysets on a skyscene can also be requested to the host by the Alpha contact.

A second Alpha contact could be engaged to react on the scene, upon a certain scenario. This means that a skyscene can interact with another skyscene from another Alpha contact. An action, a movement, a sound, literally any event can trigger response upon another skyscene can be adapted as audiovisual communication or response between two or more Alpha contacts (e.g. a divided melody between two Alphas, an experiment taking place in two or more different locations, etc.).

Two or more Alpha contacts can also prepare and rehearse a common skyscene or multiple skyscenes according to the scenario. Audiovisual response between them can be the basic means of interaction but, literally, pure imagination is the limit.

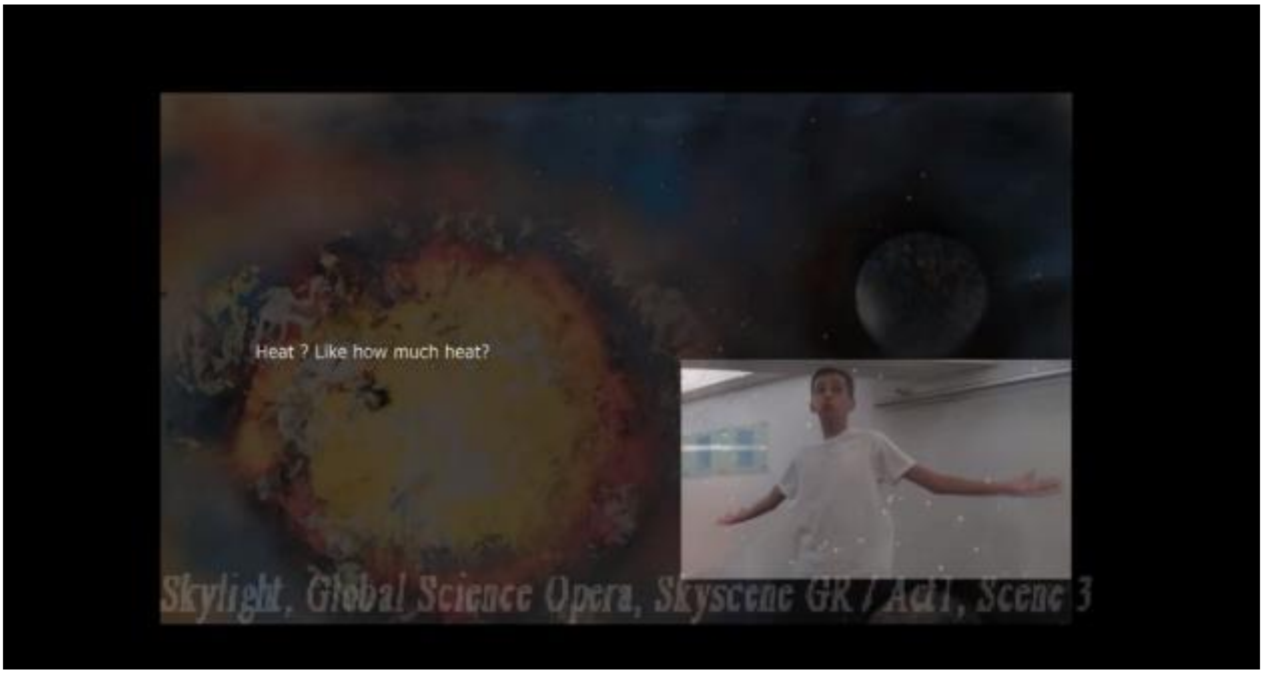
(2) Medium (synchronous)

Medium interactivity may include one powerpoint presentation up to five slides and an audio or audiovisual event. These slides will serve as background or side images of the main skyscene as described above.

(3) Low (asynchronous)

Low interactivity includes a video/audio or powerpoint skyset uploaded to skystage and the possibility of participating with chat. No live online event will be prepared.


Oh, there is a long story full of
energy, density, gravity and heat
Skylight, Global Science Opera, Skyscene GR / Act1, Scene 3


Heat ? Like how much heat?
Skylight, Global Science Opera, Skyscene GR / Act1, Scene 3

7. Assessment

GSOrt activities are evaluated through constant communication between the members of the community. Additional evaluation through online questionnaires is provided by the CREATIONS consortium.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

GSOrt demonstrator aims to develop and promote advanced and innovative videoconference capabilities used as tools for blending Science-through-the-Arts activities with traditional science teaching. This action encourages the development of a live & interactive network of remote web-channels that can link together remote communities in areas were access to music-education practice is scarce or impossible. If Music is an act of performance in which many musicians collaborate together in order to create it ("sympraxis"), then internet can be conceived as a live virtual stage in which many remote participants produce a live concert using multiple-site videoconference as a tool. It is a music (cultural) event created by students assisted by their teachers. All places collaborate together from a distance so as to produce a web-concert as a final event ("dromenon").

Science-teaching practices such as "Learning Science Through Theatre", Junior Science Café that have been thoroughly described through the CREAT-IT project can fully support the development of an associated Teachers Academy endorsing the GSOrt learning activities.

Teacher Academy of reference:

http://www.opendiscoveryspace.eu/topic-courses/live-music-education-academy

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Conference Book URL:
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Paper URL: http://connect.ea.gr/ndste2014paper/

D3.2.38 CREATIONS SUMMER SCHOOL

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Giannis Alexopoulos (EA)
Code:	D 3.2.38	**Contributors:** Sofoklis Sotiriou (EA), Zacharoula Smyrnaiou, Menelaos Sotiou, Elena Georgakopoulou (NKUA)
Version & Date: V1, 25/5/2016		**Approved by: NKUA**

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Astroparticle physics, history of the Universe.

1.2 Type of Activity

Summer school for students including lectures, workshops, visits to Research Infrastructure (physical visits/ virtual visits), use of online analysis tool, science café, public presentations, short theater Play and performance. The activity can be characterised as a Small scale Activity at local or national level.

1.3 Duration

5 days

1.4 Setting (formal / informal learning)

Both formal and informal setting. Students work in school classes & labs, visit research centers (physically or virtually), perform on theater stages etc.

1.5 Effective Learning Environment

- Communities of practice (Students groups)
- Dialogic space / argumentation (Science café)
- Arts - based
- Experimentation (Science laboratories and eScience applications)

- Simulations (digital/physical, computer labs)
- Visits to research centres (virtual/physical)
- Communication of scientific ideas to audience (theater stage)

2 Rational of the Activity / Educational Approach

2.1 Challenge

Astroparticle and High Energy Physics is a domain of science that is between top priorities of cutting edge research. Questions like, "what are the basic building blocks of matter?", "What are the fundamental forces of nature?", "Could there be a greater underlying symmetry to our universe?", still remain to be answered. Particles such as neutrinos or Higgs bosons are expected by revealing their secrets to play a major role in putting the pieces of the puzzle in the right places and tell us the history of the universe.

More specifically neutrino's particular features and properties, combined with the fact that its mass is very small, nearly zero, offer neutrino a unique advance to carry the information regarding its generating point, unchanged, at enormous distances. Furthermore neutrinos penetrate matter without being absorbed. Therefore, the information they transfer may be from interior of the celestial bodies. On the other hand, Higgs boson interacts with both bosons (particles that carry fundamental forces) and fermions (particles that make up matter), confirming the prediction by the Standard Model that all elementary particles acquire mass via the all-pervasive Higgs field. The stronger a particle interacts with the Higgs field, the heavier is. Without mass, atoms would not exist. Discovery of the Higgs boson has opened up whole new windows in the search for new physics.

Concepts as these described above, usually are not studied thoroughly or even included in the curriculum. In this framework the challenge in which this demonstrator responds to, is the creation of an activity at both an in & out of school context, such as a summer school for students, based on merging different CREATIONS demonstrators. Basic object of the summer school is to get students in contact with complex science subjects, how scientists work and inquiry based learning, using formal and informal science education tools (e.g. school labs, visit to research centers) combined with art (e.g. storytelling, performance), raising at the same time the interest of students in science and art as well.

2.2 Added Value

Summer school is a scheme that could add value to the existing (or future) initiatives and demonstrators of CREATIONS project. Due to its nature, which incorporates elements from both formal and informal settings, summer school curriculum can take advantage of a variety of practices and tools which included in CREATIONS demonstrators according to its learning objectives and outcomes. For instance Messini summer school used and combined practices from "Learning Science Through Theatre", "CMS virtual visits" and "Hypatia" demonstrator. In addition a summer school activity can act as starting point for further activities at national or international level.

3 Learning Objectives

3.1 Domain specific objectives

- To introduce students to Astroparticle physics concepts such as neutrinos, Higgs boson, neutrinos' telescopes, etc.
- To introduce students to the concept of gravitational waves.
- To introduce students to the History and evolution of the universe.
- To introduce students to the way a researcher works in the field of Astroparticle and High Energy physics.
- To guide and support students, create and present their own science stories (regarding their acquired knowledge) in form of short plays.
- To engage students in simulated robotics problems relevant to the educational scenario of the summer school.
- To introduce and support students to develop solutions using the Scratch visual programming language.

3.2 General skills objectives

Students will be able to :

- Engage in scientifically oriented questions.
- Give priority to evidence in responding to questions.
- Formulate explanations from evidence.
- Connect explanations to scientific knowledge.
- Communicate and justifies explanations using creative approaches via art based activities
- Work collaboratively as members of a team

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aims of the demonstrator is

- To introduce students in complex science topics.
- To present the connection between Micro Cosmos and Cosmos.
- To introduce students to the way science research is conducted.
- To present alternative approaches.
- To engage students that have different interests, in science.
- To combine art and science in an effective way, enhancing the creative thinking of students.

4.2 Student needs addressed

This Summer school demonstrator aims to satisfactorily address to numerous recognised students' needs such as:

- Curiosity and interest concerning major science subjects such as the birth and the evolution of the universe.
- Familiarize with Inquiry based learning process
- Collaborative learning.
- Enhance creativity and imagination.
- Communicate effectively their acquired knowledge.
- Identification with scientists and researchers as professional role models

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5 Learning Activities & Effective Learning Environments

Science topic: **Astroparticle physics, particles accelerators, History of the Universe.** Relevance to national curriculum: **Collision, momentum conservation, waves interference, dual nature of mutter (wave-particle).** Class information Year Group: **Senior high school.** Age range: **16-18** Sex: **Both.** Pupil Ability: **The scenario allows space for pupils of various abilities to participate.**	Materials and Resources *What do you need? (e.g.* printed questionnaires, teleconference, etc.) **Lecture room with projector, teleconference platform, space for computer lab, space for experimentation, transportation.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?* **In school classes or lecture halls, school labs, in research centers (physically or virtually), in places relevant to art (e.g. theaters), In public science café** *Health and Safety implications?* **None** *Technology?* **- Computers with internet access, projector and basic video conferencing equipment.** *Teacher support?* **Lecturers of the presentations or facilitators of the workshops are responsible for each day teoritical/practical activities of the summer school.**
Prior pupil knowledge: **Advanced level of knowledge in Physics. Basic understanding of elementary particles and electromagnetism**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

Day 1: Students will learn about the elementary particles, standard models, history of the Universe and the connection between Micro cosmos and Cosmos.

Day 2: Students will learn about important principles of high energy physics, subatomic particles and the structure of matter. Secondly they will learn how to work like actual researchers by evaluating and analyzing real data from the ATLAS experiment at CERN. They will visit virtually a large infrastructure research institute (CERN- ATLAS EXPERIMENT) at learn about the science, engineering and technology involved in particle physics experiments. Also they will visit physically an Astroparticle research institute (NESTOR at Pylos) and learn about about neutrinos' detection and how science researchers in the field of Astroparticle physics work.

Day 3: Students will learn about the properties of gravitational waves and the information they carry. Furthermore they will start to learn how to develop short science stories in order to communicate their acquired knowledge.

Day 4: Students will learn about how particle accelerators work. Also students will engage in simulated robotics problems and learn how to develop solutions using the Scratch visual programming language. Furthermore they will start to create a short play from the science story they developed.

Day 5: Students will learn about basic principles of science communication and the will finalize their short play in order to perform it and communicate their new knowledge.

Assessment	**Differentiation**	**Key Concepts and Terminology**
The short science stories created by the students and their acting performance will be analyzed and will work as an assessment tool. Additionally the acquired knowledge and skills by the students can be checked through briefs questionnaires.	*How can the activities be adapted to the needs of individual pupils?* Activities can be customized to the students' learning needs according their age as well as their prior knowledge and native language.	Science terminology: **Neutrino, Higgs boson, gravitational waves, particles detector, accelerator, GeV, hadrons, leptons, particle collisions, Standard model, Big Bang.**

		Arts terminology: **science stories, short plays, script, performance, acting, sketches**

Session Objectives: During this scenario, students will be introduced to advance scientific knowledge concerning elementary particles, the Higgs boson and gravitational waves either. Students will also learn to investigate scientific questions using the steps of inquiry learning process. Additionally they will gain notable programming experience and get familiar with concept such as data collection and processing, the role of sensors in a robot, control of its function Finally they will learn to use creative approaches in order to communicate this knowledge learning.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental	**1.** Students engage in dialogue with teacher/lecturer Through this discussion, students along with the help of the teacher, pose investigative questions. For example, How we can see back in time? Is light the best way? Are neutrinos an option?	**1.** Teacher/ lecturer delivers a lecture to the students regarding the History of the universe. Dialogue on the evolution of the universe with the student begins.	

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	design and collaborative work, as well as in the initial choice of question.	Are gravitational waves an alternative?		
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	**1.** Students gather evidence regarding the LHC accelerator, the discoveries it made about the elementary particles and how they can be classified in families. **2.** Researchers are discussing with students physically or virtually, presenting their work. Students gather evidence **3.** Students gather evidence about gravitational waves.	**1.** Teacher/facilitator delivers presentations regarding principles of high energy, physics subatomic particles, accelerators etc. **2.** Teacher/facilitator organizes physical or virtual visits to large infrastructure research institutes (CERN/ATLAS Experiment-NESTOR/Neutrinos detection). **3.** Teacher/facilitator presents ISE Learning Scenario: **Gravitational Waves in Class** concerning the	

		4. Student listen to the argumentation and gather evidence.	gravitational waves and their properties. **4.** Teacher/facilitator organizes a public science café.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	**1.** Students use the HYPATIA tool and examine a number of actual events that were detected by the ATLAS experiment. Based on the evidence they have gathered before, they analyze the events, they recognize different tracks of muons comparing to electrons and finally they "discover" the Higgs boson.	**1.** Teacher/facilitator help students to use HYPATIA tool, answer to student questions and provide the needed clarification.	

		Students analyze the information they gathered concerning gravitational waves.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	**1.** Students discuss their findings from the previous phase and decide which of their results are valid. **2.** Students collaborate in teams and choose the explanations they will adopt regarding the investigative questions that have been posed and then they proceed with the development of the science stories .	**1.** Teacher/facilitator helps students to interpret their findings. **2.** Teacher/facilitator helps students identify possible misconceptions.	Creation of science stories by the students, storytelling, script writing.

Phase 5: **CONNECT:** Students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	**1.** Students discuss their results and the conclusion they reach, in comparison with already known and reliable data and facts in the science literature. **2.** Also students make the connection of the science stories they develop with other disciplines such as script writing, acting, directing and start to convert their story into a short play.	**1.** Teacher/facilitator discusses with the students the meaning of possible deviations. **2.** Teacher/facilitator coordinates and encourages the groups of students.	Acting, script writing, directing etc.
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of	**1.** Students teams communicate the new knowledge they acquired, by performing their	**1.** Teacher/facilitator organizes and supports the final performance of the students.	Finalization and Rehearsals of students' short plays

COMMUNICATE: students communicate and justify explanation	the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	science stories in form of short plays in front of the audience.		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	**1.** Students discuss with each other and with the teachers/facilitators of the summer school about the main characteristics of their work both in science and art/creativity field. What was successful, what wasn't so. **2.** Students performance is also evaluated by those who watch their short plays (scientists, teachers, l artists, science communicator experts, even general public).. **3.** Students can compare their views	**1.** Teachers/ facilitators discuss with the students what went well and what did not concerning the summer course Evaluate whether all students were involved in the creative inquiry process 2. Teachers/ facilitators take part in the evaluation process.	

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		regarding the science concepts they dealt with before and after the summer school they participate in and think which parts of the summer course influenced them the most.		

6 Additional Information

As an example of a summer school program, the agenda of CREATIONS summer school at Messini is given.

Messini Summer School Agenda

	Thursday July 28th	Friday July 29th	Saturday July 30th	Sunday July 31st	Monday August 1st
08:00-09:00		Breakfast	Breakfast	Breakfast	Breakfast
	Students' arrival	**09.00-10.00** **The experiment of the century in a school lab** *Cristina Kourkoumelis* *University of Athens* **10.00-11.00** **Virtual visit to ATLAS Experiment at CERN** *Ioannis Gialas* *University of the Aegean* **11.00-12.30** **Laboratory exercise** *Cristina Kourkoumelis*	**10.00-11.30** **Detecting Gravitational Waves** *Manolis Chaniotakis* *Ellinogermaniki Agogi* **11.30-13.00** **Make yor** **Create your own science story** *Spiros Kitsinelis* *Menelaos Sotiriou* *Zacharoula Smyrnaiou* *University of Athens*	**9.30-10.30** **Higgs particle: Past,** **Present and Future** *Michalis Karatzinos* *CERN* 10.30-13.00 Simulating Robotics using Scratch– Communication Protocols *Georgios Papadopoulos* *Ellinogermaniki Agogi*	**10.00-11.00** Creativity: Learning Science through Art *Spiros Kitsinelis* *Menelaos Sotiriou* *Science View* **11.00-13.00** Students' presentations

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		Georgios Vasiliadis *University of Athens*			
13:00-14:00	**Lunch**	**Departure to Pylos**	**Lunch**	**Lunch**	Students' departure
	17.00-17.30 **"This small, this Great World"** *Sofoklis Sotiriou* *Ellinogermaniki Agogi* **17.30-19.30** **Dialoques regarding the Microcosm and the Universe** *Sofoklis Sotiriou*	**13.30-14.30** **Visit to NESTOR Research Instute (Presentation)** *Sofoklis Sotiriou* *Ellinogermaniki Agogi*	Free Time	**15:00-17:00** Automatic control using scratch *Georgios Papadopoulos* *Ellinogermaniki Agogi* **17.00-18.00** **Create your own science story** *Spiros Kitsinelis*	

	Ellinogermaniki Agogi *Spiros Kitsinelis* *Menelaos Sotiriou* *Science View*			*Menelaos Sotiriou* *Zacharoula Smyrnaiou* *University of Athens*	
		Swimming-Lunch **(Methoni)**			
		Free Time	**19.00-23.00** **Visit to the traditional village of Vanada, Messinia. – Science Café** *Sofoklis Sotiriou* *Ellinogermaniki agogi* *Spiros Kitsinelis* *Science View*	**Free Time**	
20:00-21:00	**Dinner**	**Dinner**	**Dinner**	**Dinner**	

Table1. Agenda of CREATIONS summer school at Messini

Link to official website of CREATIONS Summer school at Messini:

http://messini.ea.gr/

Picture 1. Snapshot of Summer school's official site Homepage

7 Assessment

The methodological tool of content analysis was used to analyze the data collected from the observation of the dramatized scenarios and to connect them to the characteristics of Embodied Learning. Based on the theoretical framework presented in brief below there has been developed a system of categorizing the ways which students through Embodied Learning: a) represent scientific content/generate meaning, b) communicate with one another, c) entertain the audience while they dramatize scientific scenarios which take into account both the teaching of sciences and theatre techniques.

Embodied Learning constitutes a contemporary pedagogical theory of learning, which emphasizes the use of the body in the educational practice and the student-teacher interaction both inside and outside the classroom and in digital environments as well. Using the body is essential in concept representation and communication while this is also confirmed by the emphasis other fields and cognitive objects place on the body as a learning tool, such as dance theatre, kinesiology, athletics even Mathematics and Physics. All these cognitive objects have student collaboration, movement and the process of cognitive development as a common denominator.

Traditionally the body has not been used in education. Every involvement of the body had been consistently excluded from the educational practice, the process of learning and the interaction among students. The notion of Embodied Learning was not known and therefore not acceptable by the educational community such as the teachers and the students. Consequently it was difficult to understand that the body does not solely constitute a means of knowledge, or a mediator, but it also reflects the student's interaction with the environment.

Embodied Learning is closely related to constructivist models and to modern educational theories regarding the role of the teacher, of the student and of learning itself in the educational practice. Embodied Education has been defined as the basic concept which includes Embodied Teaching and Embodied Learning [1]. In fact, the terms Embodied Learning and Embodied Teaching are used alternately to refer to new scientific and educational practices [2].

In accordance with the constructivist principles, the body is used both inside and outside classroom for experiential learning and is not treated as a place of learning. The principles of Embodied Learning provide answers to questions related to the ways knowledge is constructed by students as they leave behind them the academic model of perceiving knowledge and treat each student as a whole, while they view everyone's body as a tool for knowledge construction and as a knowledge carrier [3], [4], [5], [6], [7]. Language and full-body motion have been studied as an integral means through which students express thoughts and meanings when they interact with a set of collaborative digital games designed by the researchers [8] in creative and innovative teaching approaches [9]. This way, each student is placed in the center of the educational process, while disinterestedness is transformed into active participation and emotional neutrality into cooperation.

In Embodied Learning, new knowledge is affected by the conditions it is used and by the types of activities the student is expected to participate in. Consequently, the following parameters should be taken into consideration when designing an activity:

a) cognitive involvement to the topic, cognitive processes, representation of a scientific notion
b) body movements
c) expression of the student's feelings
d) clarity of instructions
e) holistic design of activities
f) student cooperation
g) ability of students to apply acquired knowledge to new environments

It becomes evident that Embodied Learning is in accordance with new educational practices, as it uses personality as a whole, and promotes the way students learn and not the content of learning in the learning process. However, only few studies have been conducted to link Embodied Learning to the dramatization of educational theatrical scenarios and to the representation of scientific concepts and knowledge, with the aim of developing student creativity and critical thinking, their active participation to the learning process, their deep understanding of scientific notions and phenomena and the interdisciplinary connection of Sciences to forms of Art.

8 Possible Extension

The flexibility which characterise the curriculum of a Summer school course, give us the choice to adopt educational activities from a variety of different CREATIONS demonstrators according to the general educational scenario and the chosen learning objectives of the course. For instance, Science&Art@School workshops, Student Parliament, Global Science Opera and GSOrt (and a lot more) are demonstrators which could be merged and produce a number of different appealing for the students new demonstrators. Furthermore by motivating students from more than one country to participate in a summer school course like this, that could lead to a large scale international activity, where students from different countries get in touch, communicate and share their ideas, regarding science and arts.

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D3.2.39 The Sound of the Earth

Project Reference:	665917	**Author:**	Emmanuel Chaniotakis (EA) Petros Stergiopoulos (EA)
Code:	D 3.2.39	**Contributors:**	
Version & Date: v1. 31/5/2017		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.2 Subject Domain

Geology\ Earthquakes\ Earthquake Detection

Music\ Sonification of experimental data

1.3 Type of Activity

In school activity through which students are introduced to the science behind earthquake formation and detection through sonification of experimental data. They will sonify earthquake data and will be able to turn the earthquake waveforms in musical patterns through which they will be able to listen to the music of the earth.

Duration

1 week

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.
- Online e-Learning applications and educational content repositories: Open Discovery Space.
- Arts based.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

- Introducing students to the method of sonification of experimental data.
- Introducing students to the science of earthquake formation and detection.
- Using sonified earthquake data to understand and measure fundamental characteristics of earthquakes as well as learn how to disentangle earthquakes from different sources.
- Understand the similarities between visual representations of an earthquake and audible representations of frequencies

The standard way to depict earthquakes and explain their characteristics, has been the use of "snapshots" of the waveforms measured by seismic stations across the earth. By studying and combining the information obtained by these static images, scientists are able to understand the properties of earthquakes, as well as discover the properties of their sources as well as their generation mechanism. However, using these visual displays alone presents the problem of properly explaining even the most fundamental characteristics of seismic waves, such as the waveforms of Primary (P) and Secondary (S) waves as well as more complex properties of seismic waves such as their frequency content, their attenuation and others. This is particularly important in the field of science education, in which students do not have prior knowledge concerning earthquakes. To address these topics, data sonification or audification builds on the people's ability to learn through auditory stimuli and be able to analyse complex phenomena through the vehicle of sound cues such as amplitude, pitch and frequency.
In this demonstrator, students will be introduced to earthquake data and will investigate earthquakes' fundamental characteristics by converting these data into sounds.

Students will investigate the earthquake magnitude scales by identifying them with sounds of natural phenomena of equal energy output, will analyse, investigate and sonify waveforms of earthquakes detected by school based seismometers developed in the framework of the project: Students Study Earthquakes (http://sse-project.eu) in a playful fashion, and finally compose their own music based on the sound of the Earth itself.

2.2 Added Value

- Students are introduced to the sonification technique which can be applied in various physical phenomena spanning from elementary particle collisions to the study of exoplanets and beyond.
- Students combine the scientific quest for understanding the nature of earthquakes with music using cutting edge ICT technologies, thus participating in a unique STEAM experience.
- Earthquake sonification can be used to teach earthquakes to visually impaired learners.
- Linking music to scientific concepts and combining different representational systems.

3. Learning Objectives

3.1 Domain specific objectives

The domain specific objectives of this Demonstrator are:

1. The students apply fundamental physics of waves in order to understand the process of sonification of earthquake data.
2. The students learn about the generation and detection principles of earthquakes as well as their fundamental characteristics and observable quantities.
3. The students learn how to tell apart earthquakes created by different sources based on the interpretation of experimental data.
4. The students understand the correlation between numerical data, mathematical graphs and audible spectrum.
5. Inquiry process of scientific concepts.
6. Recognize, analyse and imagine alternative explanations and models.
7. Combining science with art (Music).

3.2 General skills objectives

1. The students make sense of scientific data and produce artistic representations of them.
2. The students enhance their analytical and synthetical skills.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator combines scientific inquiry with music education. Students investigate the characteristics of earthquakes using real data and then sonify the data in order to produce a musical synthesis from them. Students Learn about the Science behind Earthquakes through ICT enhanced means. They forge connections between sound and earthquakes taking into account their wave nature. Students learn about the principles of data sonification and sound compression.
After this, the students choose data from earthquakes which took place in the Eastern Mediterranean and perform their sonification using a self-developed sonification protocol thus playing their own sound of the earth. The teacher presents the fundamental concepts and leads the students subtly in the whole process.

4.2 Student needs addressed

Relevant student skills:
- Active use of different semiotic systems so as to acquire knowledge
- Interconnection of science, creativity and culture.
- Negotiation with notions which are no part of the curricula but are important for everyday life.

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5. Learning Activities & Effective Learning Environments

10Question-eliciting activities

- Introductory material and questionnaire addressing the basic needs of the exercise will be offered to the students to explore before the beginning of the exercise.
- Students discuss the fundamental characteristics of waves: Frequency, wavelength, propagation velocity, amplitude. They discuss the differences between transverse and longitudinal waves and apply their knowledge to different kinds of waves.

  They discuss the nature of sound and identify the spectrum of human hearing, namely 20 Hz to 20kHz. By listening to different given sounds, they identify the frequency and amplitude of the sound.
- Students can work with these tools to find out more about the fundamental characteristics of sound:

  http://www.iknowthat.com/ScienceIllustrations/sound/science_desk.swf

  https://phet.colorado.edu/en/simulation/sound
- Introductory lecture about earthquakes.
- Introduction to data sonification.

11 **Active investigation**

- Introduction to earthquake scales: Richter and Mercalli and symbolic sonification by using the sound of a known phenomenon of similar energy output to describe earthquakes of a specific magnitude scale.
- Presentation of real earthquake data and discussion of their fundamental characteristics in terms of frequency and amplitude. Presentation the method employed by scientists to find the earthquake epicenter using information from earthquake waveforms. Interactive demonstration using online interactive maps.
- Sonification of real earthquake data using the time compression technique and identification of S- and P- waves using auditory means. Students divide in groups and sonify the data of earthquakes, in order to understand the time compression technique. Students discuss the frequency spectrum of sound and experiment with it in order to find out the boundaries of their hearing from infra to ultrasound.
- Students are provided with sonified data of an earthquake from different earthquake stations and try to identify the earthquake epicentre by correlating the time difference of S- and P- waves they hear with epicentre distance. Comparison with the location of the epicentre measured using a visual description of data.
- Follow up activity 1: Students work further with data sonification in order to correlate earthquake amplitude with the notes of the musical scale. By using the data obtained over a long time from a station, students synthesize the music of earthquakes.
- Follow up activity 2: Students create a performance using sonified earthquake data.
- Follow up activity 3: Students develop an algorithm which can transform the real time data stream of a seismic station to music. The user will be able to understand when an earthquake has started by listening to the changes in the sound produced by the P-waves. Such applications could be used to help the in-time evacuation of buildings, prevention of landing of aircrafts or stopping of trains before the most catastrophic S- and Love waves of an earthquake reach a specific territory.

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Science topic: Physics \ Waves, Geology\ Earthquakes, Music\ Sonification, Musical Scales Class information Year Group: 2nd and 3rd class of Senior High School Age range: 15-17 Sex: both Pupil Ability: Basic computer usage required	Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection. Software for processing earthquake data. Software for data sonification. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In a computer laboratory and a classroom. *Health and Safety implications?* None *Technology?* *Teacher support?* The teacher will provide the students with preliminary material and is advised to discuss with them before the beginning of the activity. The relevant material can be found in this online virtual community: (http://portal.opendiscoveryspace.eu/community/sound-earth-848393)
Prior pupil knowledge: Students should be familiar with basic characteristics of waves: frequency, amplitude, wavelength, propagation velocity. A basic understanding of sound in terms of both empirical as well as analytical characteristics is desired. Also, basic knowledge on visual representation of scientific data in the form of graphs as well as basic manipulation of such graphs is desired. Basic use of PC and analysis software is desired.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* 1. The students apply fundamental physics of waves in order to understand the process of sonification of earthquake data. 2. The students learn about the generation and detection principles of earthquakes as well as their fundamental characteristics and observable quantities. 3. The students learn how to tell apart earthquakes created by different sources based on the interpretation of experimental data. 4. The students make sense of scientific data and produce artistic representations of them. 5. The students enhance their analytical and synthetical skills.		
Assessment Content knowledge is assessed through specific questions and exercises throughout the in-class activity and creativity as well as science motivation are assessed through pre-post questionnaires.	**Differentiation** This activity can be used by students with visual impairments. Furthermore, it can be used by students who are arts-oriented without much adaptation.	**Key Concepts and Terminology** Data processing, data analysis, earthquake, waveform, sonification, waves, S-P waves, frequency, amplitude, musical scales. **Science terminology:** waves, S-P waves, frequency, amplitude, earthquake, Data processing, data analysis

		Arts terminology: sonification, musical scales.

Session Objectives:

This demonstrator combines scientific inquiry with music education. Students investigate the characteristics of earthquakes using real data and then sonify the data in order to produce a musical synthesis from them. Students are introduced to the sonification technique which can be applied in various physical phenomena spanning from elementary particle collisions to the study of exoplanets and beyond.

Students combine the scientific quest for understanding the nature of earthquakes with music using cutting edge ICT technologies, thus participating in a unique STEAM experience.

The link to the online pre-activity can be found here:

(http://portal.opendiscoveryspace.eu/edu-object/earthquakeshighschool-837786)

The link to the "Sound of the Earth" Online community with the relevant resources and guidelines can be found here:

(http://portal.opendiscoveryspace.eu/community/sound-earth-848393)

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	Students play a game: By studying the earthquake Mercalli and Richter scales, they match the magnitude of an earthquake to the sound of a phenomenon with similar energy output. Now students move to earthquakes and discuss their wave behavior. By examining a given earthquake waveform, they try to figure out an average frequency. Can we hear earthquakes themselves? If not, how could we	Background knowledge on waves and their fundamental characteristics is desired. After introducing students to earthquakes, the teacher presents them with the Richter and Mercalli scales: (Orienting and Asking Questions: http://portal.opendiscoveryspace.eu/edu-object/earthquakeshighschool-837786) Students should already have a background in earthquakes, following the question eliciting	

		make an earthquake audible?	activities. http://portal.opendiscoveryspace.eu/edu-object/earthquakeshighschool-837786 The teacher should highlight the fast, longitudinal P- and the slower, transverse S- waves of earthquakes. In the discussion of earthquake behavior, an earthquake waveform should be presented to them, such as the one presented in the "Investigation" section of the Earthquake related lesson presented above. Students understand the S- and P- components of the waveform. By observing the S- and P- components, the students estimate the frequencies of these waves and discuss if they can be audible. (Note: Earthquakes have	

			usually frequencies in the domain of 0,1 to 100 Hz thus are hardly audible to the human ear with its 20 Hz threshold for hearing).	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students follow the procedure outlined by their teacher to view the spectrograms of specific earthquakes. Students note the earthquakes' duration and figure out their specific characteristics. Students divide in groups and following their teacher's instructions, they transform the seismic data in audio. They observe the difference of duration and frequency between	Students are introduced to the process of data sonification. They use data from school seismographs which can be found in the form of .sac files here: http://sse-project.eu/?m=7 They use a .sac file viewer and choose the earthquakes of interest to them. The teacher makes sure that students note the duration of the earthquake. The Purpose of this part of the activity is the students to make sounds audible.	Experimentation with sounds of earthquake.

		the seismogram data and the audio data. They discuss the method applied. By using the audio processing software, students experiments with the sounds of earthquakes.	**<u>Sonification Method nr.1</u>** 1. Students transform the .sac to .psn files using the "sac to psn" applet which can be downloaded from this website: http://jclahr.com/science/psn/mcclure/sac/index.html (The .psn files can be viewed via winquake: http://www.seismicnet.com/software.html) 2. Students transform the .psn to .wav files through the "psn to wav" applet from the same website. 3. Students process the .wav file using audacity (http://www.audacityteam.org)or another sound processing programme.	

			4. Students listen to the .wav file they produced with the sound processing software and determine its frequency. By observing its duration, they compare to the duration of the earthquake they measured. To make a waveform audible, you compress it so that the frequency increases, therefore the duration decreases.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	The teacher provides students with .sac files of an earthquake measured by different stations. The teacher should provide the students with the distance of each station	Students are offered the .sac files of an earthquake measured by different stations.	Students perform their musical synthese s by combinin ing the

		from the epicenter of the earthquake. Students view the waveforms of the earthquakes and measure the S- and P- wave time intervals: Tsp_True. Students apply their prior experience and sonify these seismograms. Students experiment to see if they can disentangle the S- and P- waves in terms of sound. They measure the duration of the earthquake waveform before sonification (Tbefore) and of the waveform that they	The teacher should stimulate a discussion concerning the fast, longitudinal P- and the slower, transverse S- waves of earthquakes. In the discussion of earthquake behavior, an earthquake waveform should be presented to them, such as the one presented in the "Investigation" section of the Earthquake related lesson presented here: http://portal.opendiscoveryspace.eu/edu-object/earthquakeshighschool-837786 . Students understand the S- and P- components of the waveform and identify that they are detected with a time difference which is proportional to the distance of the earthquake epicenter to the detector.	waveforms they have analyzed with the sounds of different musical instruments in an online environment. They match waveform amplitude to notes and using a sonificati

		produced after sonification (Tafter). Students measure the time interval between S- and P- waves that they listen. Tsp_sound. To find the corresponding S-P time interval Tsp_measured, they do: Tsp_measured =Tsp_sound*(Tbefore/Tafter) Students compare the Tsp_measured with Tsp_True. Students can repeat their sonification procedure to minimize the difference in Tsp_true and	After this introduction, the students follow the procedure outlined in the student section and compare the S-P time difference they measure by listening to the S-P difference they measure by observing. As an optional activity, students could try to locate the epicenter of the earthquake by using both the sonification and observation method by following the guidelines provided. **Sonification Method nr.2** 11.1 Students transform the .sac file into numerical data corresponding to time	on protocol they play their own melodies.

		Tsp_measured. What is the difference between the Tsp_measured for the different seismograms? Does it scale with distance from the epicenter of the earthquake?	(x axis) and amplitude (y axis) 11.2 With the help of their teacher they choose one note of the middle octave within the 88 note music compass. They assign this note as "0" . 11.3 Students start relating	

			each value of the y axis with the corresponding notes in step of one semitone (e.g. If C_4=0 then for positive values $C\#_4$=1, D_4=2 etc. For negative values B_3=-1, A#=-2 etc. 11.4 Students compare the horizontal values with	

				the vertical and design a timeline that matches them. The x axis values are related to their corresponding y axis values in terms of possible deviations in duration.	
			11.5	Students perform the sequence of intervals derived from the timeline	

			using easy chromatic-scale physical musical instruments or digital applications	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students make a short presentation to explain the sonification technique and the results one can obtain by sonifying earthquake data. They discuss their sources of uncertainty and methods to minimize it.		
Phase 5: **CONNECT:** students connect explanations to	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the	The students are provided with visual and audio representations produced by: - Volcanic eruptions	Teacher provides students with data from different seismic sources: http://geophysics.eas.gatech.ed	

scientific knowledge	origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	- Nuclear bomb tests - Earthquakes They discuss the different characteristics and connect them to the different possible generation mechanisms of the earthquakes.	u/people/zpeng/EQ_Music/	
Phase 6: **COMMUNICATE: ** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students discuss the merits and importance of sonification of earthquakes and beyond, both to society and to people with visual impairment.	The teacher can show this videos to students to trigger further discussion: Earthquake sonification at CERN https://www.youtube.com/watch?v=FNRQ_LuzMt4 Interactive data sonification for people with visual impairment https://www.youtube.com/watch?v=8hUIAnXtlc4	

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect on what they have learnt and answer to relevant questions posed by their teacher.	The teacher discusses with the children in order to monitor their understanding. The students reflect on the procedure they followed and answer the following questions: 1. What is the connection between the phenomenon of earthquakes and waves? 2. Are all waves audible? Visible light is a wave. Can we "hear it?" 3. Which is the lowest and which the highest sound frequency that a human ear can understand? 4. Can earthquakes be heard by human ear? During an earthquake we listen to the sound of objects moving or falling around us. Does this mean that we listen to earthquakes themselves, or to the product of the interaction of the seismic waves with our	

			environment? 5. How do we sonify a wave? Describe the method in a few words. Why does the duration of an earthquake become shorter after the sonification procedure? What is the corresponding change in frequency? 6. What are the characteristics of the earthquake that we can observe through seismic data sonification? (Examples are : variations in frequency, variations in amplitude, different components of seismic waves, such as the S- and the P-waves). 7. What are the advantages of data sonification? 8. How can we make use of the sound in order to further understand properties of other natural phenomena?	

			(Accessibility for a broader range of users, spatial distribution of sound compared to visual stimulus, the high audio response of the human ear, the fact that through sonification, the user can have a data analysis process running in the background, the connection with the arts and especially music. The teacher can refer to this article for further information: http://www.open-shelf.ca/160201-data-sonification/)	

6. Additional Information

All relevant companion resources and activities can be found in the dedicated online community of the CREATIONS portal: http://portal.opendiscoveryspace.eu/community/sound-earth-848393

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

The student motivation and creativity will be monitored using dedicated evaluation questionnaires developed by the CREATIONS consortium before and after the completion of the activity The content knowledge will be monitored throughout the lesson through dedicated questions and exercises which are done in a hands-on fashion.

8. Possible Extension

- Follow up activity 1: Students work further with data sonification in order to correlate earthquake amplitude with the notes of the musical scale. By using the data obtained over a long time from a station, students synthesize the music of earthquakes.
- Follow up activity 2: Students create a performance using sonified earthquake data.
- Follow up activity 3: Students develop an algorithm which can transform the real time data stream of a seismic station to music. The user will be able to understand when an earthquake has started by listening to the changes in the sound produced by the P-waves. Such applications could be used to help the in-time evacuation of buildings, prevention of landing of aircrafts or stopping of trains before the most catastrophic S- and Love waves of an earthquake reach a specific territory.
- Follow up activity 4: Students explore the sonification of real data from other sources such as gravitational waves, radiowaves coming from the universe, high energy physics collisions and others.

9. References

Kilb, D., Z. Peng, D. Simpson, A. Michael and M. Fisher* (2012), Listen, watch, learn: SeisSound video products, Seismol. Res. Lett., 83(2), 281-286, doi: 10.1785/gssrl.83.2.281.

D3.2.40 The ALICE Experiment @ CERN

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Emmanuel Chaniotakis (EA)
Code:	D 3.2.40.	**Contributors:**	Dr. Despina Hatzifotiadou (CERN,INFN)
Version & Date: v1. 24/5/2017		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

High Energy Physics at CERN

1.2 Type of Activity

This is a student activity taking place in both formal and informal settings, promoting the connection of school and research center. Through this activity students are introduced to the science behind the study of the Quark Gluon Plasma as it is conducted by the ALICE experiment at CERN. Students learn about CERN and investigate: strangeness enhancement, one of the most important signatures of the Quark Gluon Plasma formation, using interactive online tools to analyze real collision data. Activity can take place both in local and in national level.

1.3 Duration

5 hours

1.4 Setting (formal / informal learning)

Formal (classroom) and informal (research center).

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.
- Arts based.

2. Rational of the Activity / Educational Approach

2.1 Challenge

- Becoming a scientist for one day to participate in modern scientific research
- Employ creativity and teamwork to analyze and communicate scientific results with the general public in an artful fashion.
- Understanding advanced scientific topics beyond the reach of school curricula.

In order to understand Nature and the Laws governing our Universe, Modern Science has developed tools and techniques of sophistication far beyond the reach of school curricula. Modern discoveries are able to answer questions such as "What are we made of?", "What is the nature of mass?", "How did the Universe look like during its infancy", which were once in the realm of Philosophy and speculation. Today, these questions can be quantified and answered in cutting edge experiments, thus expanding the boundaries of human comprehension far beyond our everyday practice. In order to organize and conduct the experiments needed to verify such hypotheses, scientists form international collaborations consisting of thousands of scientists and engineers and build gigantic research infrastructures dedicated to the pursuit of fundamental knowledge.   Such an international, multicultural research infrastructure is CERN, with experiments ran by thousands of scientists aiming to discover the most fundamental laws of the Universe with unprecedented accuracy.

Students are exposed to these scientific breakthroughs through media such as TV, newspapers, blogs or social media. However, the knowledge and skills needed to be able to comprehend the science behind these discoveries, are far beyond the reach of the school curricula. As a result, dedicated outreach activities have been developed by leading organizations involved in scientific research, science education and outreach, in order to bring students in touch with modern scientific research culture, demonstrate to them cutting edge scientific achievements and cultivate the skills needed in order the students to become 'little researchers' and explore on their own the fascinating world of modern science.

In this framework, the "ALICE Experiment at LHC" demonstrator, connects students with fundamental research taking place in one of the 4 large experiments of the LHC complex at CERN, ALICE, which reproduces and studies the state of the Universe at a tiny fraction of a second after the Big Bang: The Quark Gluon Plasma.

Students learn about the research done at CERN and by working in teams, they explore and analyse real scientific data and search for the Signatures of Quark Gluon Plasma in the ALICE detector. To provide them with an inspiring experience, students connect live with a scientist at CERN and discuss their results and questions. Finally students employ their creativity and communicate their results and ideas in an artful fashion.

2.2 Added Value

- Students learn about cutting edge research at CERN and become part of it by analyzing real LHC data.
- Students work in teams to analyze and present their results.
- Students learn Physics within and beyond their school curricula and thus get inspired on science in general.
- Students discuss in real time with scientists working at CERN
- Students learn how to communicate their results in an artful fashion by employing their creativity to create a video.
- Development of analytical thinking.

3. Learning Objectives

3.1 Domain specific objectives

Students become 'young researchers' and explore cutting edge physics from their school laboratory. The students will learn about the ultimate structure of matter and its behavior under extreme conditions as they can be probed through heavy ion collisions. They will learn about Quark Gluon Plasma, the primordial substance in which quarks and gluons roamed unconfined, which existed in the Universe during the first microsecond after the Big Bang when the temperature was of the order of 1 trillion Kelvin. They explore the world of strange quarks and analyze real ALICE data to identify strange particle decays.

The learning objectives of this demonstrator are:

1. The students to Understand what Quark Gluon Plasma is.

2. The comprehension that through a high energy particle collision, students can study the Universe at its infancy.

3. Students have learnt about the conservation of momentum and energy in classical settings and now they are asked to employ them to understand data produced by subatomic particle collisions.

4. Students learn about the internal structure of matter and the importance of fundamental particles such as strange particles, which are not part of our everyday world, in understanding the structure and the Laws of the Universe at its infancy.

5. Students perform scientific inquiries.

6. Students develop critical thinking.

7. Through data analysis, students obtain scientific mindsets.

3.2 General skills objectives

Students will learn to apply their knowledge and analytical skiils to identify the strange particles produced during heavy ion collisions through their decay patterns. Through this, they will be able to learn and review curriculum based science such as the bending of charged particle tracks in magnetic fields. Furthermore, students will learn how to collaborate in order to produce high quality scientific results and combine them to comprehend the science behind the task at hand.Furthermore, students will employ their creativity and use their imagination in order to produce a video displaying the route from the theoretical conception of the idea of the existence of Quark Gluon Plasma to the experimental study of it.

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is a hands-on activity aiming to introduce the scientific culture of large research infrastructures such as CERN to students. Students investigate real particle collision data, conduct analysis and identify the physics principles behind cutting edge scientific discoveries. Students discuss with renowned scientists through online web conferences. Finally, students communicate their results and reflect on the process of scientific inquiry they used employing their creativity integrating art in their classroom practice.

4.2 Student needs addressed

In this activity, students develop their knowledge on scientific issues beyond the reach of their school curricula. They develop creative skills, critical thinking and learn how a scientist thinks by doing their own inquiries based on the IBSE model.

The students involved in this activity need to have basic knowledge of the principle of conservation of energy and momentum and its applications in collisions. Basic knowledge in the structure of phenomena related to special relativity as well as the structure of matter are desired. Students will work on PC's using the Virtual ALICE tool, therefore basic computer skills are required. Finally, students need to create a motivational video to present their results and communicate and reflect on the scientific inquiry they performed, therefore basic artistic intuition and group work are also needed. The exercise can be addressed by 16-18 year old students.

5. Learning Activities & Effective Learning Environments

12Question-eliciting activities

- Introductory material addressing the basic needs of the exercise will be offered to the students to explore before the beginning of the exercise.
- Lecture about elementary particles, CERN, LHC and heavy ion collisions at the ALICE experiment will be delivered by experts.
- Discussion/question/answer session with the students and teachers and experts.

13 **Active investigation**

- Introduction to the software that will be used.
- LHC interactive event analysis focusing on strange particle identification.
- Video conference with CERN expert at the ALICE experiment control room.
- Creation of a video communicating their results and reflecting on the inquiry procedure students used during their investigation.

More Specifically:

- Students will be introduced to the scientific culture of large research infrastructures such as CERN and use the scientific inquiry as real High Energy Physicists do. Finally, they will reflect on their activities through creativity enhanced artful interventions.

Science topic: High Energy Physics/Nuclear Physics. Class information Year Group: 2nd and 3rd class of senior high school Age range: 16-18 Sex: both Pupil Ability: Basic computer usage required	Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. Virtual machine to install the ALICE analysis tool, or Linux software. A projector. Internet connection. Android or PC application to create a video. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In a computer laboratory and a classroom. *Health and Safety implications?* None *Technology?* *Teacher support?* The teacher will provide the students with preliminary material and is advised to discuss with them before the beginning of the activity. The relevant material can be found in this online virtual community: http://portal.opendiscoveryspace.eu/community/alice-experiment-cern-848059
Prior pupil knowledge: The students involved in this activity need to have basic knowledge of the principle of conservation of energy and momentum and its applications in collisions. Basic knowledge in the structure of phenomena related to special relativity as well as the structure of matter are desired	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* The aim of this intervention is for the students to understand how scientists analyze real experimental data of heavy ion collisions to infer the existence of Quark Gluon Plasma and study its properties. They will learn about the signatures of Quark Gluon Plasma in a Particle Detector Such as ALICE and understand the procedure of data analysis using real LHC data.		
Assessment Content knowledge is assessed through specific questions and exercises throughout the in-class activity and creativity as well as science motivation are assessed through pre-post questionnaires.	**Differentiation** The activities described in this demonstrator refer to very advanced scientific concepts and the attempt to bring them in the classroom. As a result they have specific content knowledge requirements. Variants of these activities including a presentation and creative expression of students combined with a virtual visit can be performed by more students without tight content knowledge restrictions.	**Key Concepts and Terminology** Heavy ion collision, Data Analysis, Invariant mass calculation, strange particles, Quark Gluon Plasma Formation, interview to a scientist **Science terminology:** Heavy ion collision, Data Analysis, Invariant mass calculation, strange particles, Quark Gluon Plasma Formation **Arts terminology:** Graphic display of particle collisions, Video design

Session Objectives:

In the framework of this demonstrator, students will analyze data from the ALICE experiment at CERN regarding the experimental signatures of Quark Gluon Plasma Formation. Concluding their activity, students should be able to describe what happens during a heavy ion collision at CERN and discuss the strange particles enhancement experimental signature of QGP. In the end of the activity, students will create a motivational video communicating the findings of their analysis and reflecting on the scientific inquiry method employed by scientists at CERN.

The link to the online activity can be found here:

http://portal.opendiscoveryspace.eu/edu-object/alice-experiment-cern-848313

The link to the ALICE Experiment Online community with the relevant resources and guidelines can be found here:

http://portal.opendiscoveryspace.eu/search-resources-in-community/848059

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge	Students get introduced to key concepts and ideas in elementary particle physics and particle collisions, with the specific focus on the production of Quark Gluon Plasma and its detection by	Teachers make sure that they have a computer lab with internet connection and a projector. In order to install the software needed to facilitate the students' investigation, teachers	

	and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	the ALICE experiment at CERN.	should follow the guidelines presented here: http://portal.opendiscoveryspace.eu/edu-object/alice-experiment-cern-teacher-guidelines-848368 Teachers have already provided introductory material to the students : http://portal.opendiscoveryspace.eu/edu-object/particle-adventure-848306 http://portal.opendiscoveryspace.eu/edu-object/alice-and-soup-quarks-and-gluons-848065 They should have also already reviewed fundamentals of classical	

			collisions in the classroom as well as done some brief introduction to special relativity and especially the mass energy relationship of Einstein: https://youtu.be/Xo232kyTsO0	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students explore the most fundamental signatures of Quark Gluon Plasma formation in the LHC: The enhancement of strange particles. They learn about the strange particle decays and learn how ALICE scientists visualize this decays and analyze them to find out the parent particle from which the decay particles were produced through the invariant mass calculation.	The teacher acts as a mentor and makes short targeted interventions allowing students to discover the scientific results presented on their own.	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	The students use the ALICE Online visualization tool to explore strange particle production in proton-proton collisions at CERN. They work in groups and identify the parent strange particle according to the decay particles topology and invariant mass. Finally they save their results. After that the students combine their results to a common folder which is offered to the teacher.	The teachers, having already ensured the proper functionality of the technical infrastructure, closely monitor and guide students throughout their exercise. Students should work in groups of 2-3 per computer. After the analysis is completed, the teacher takes the data of the students via usb and combines them following the activity guidelines. The final histograms are displayed on the projector by the teacher.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The students summarize their results and discuss among them and with the teacher the combined data distributions. They mention the obstacles and the difficulties they had in strange particle decay identification.	The teacher should help students interpret the histograms and discuss their relevant attributes.	

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		Finally, students watch the video of how a large scale analysis using strange particle decays produced in heavy ion collisions is conducted and what are the potential outcomes.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students make a video-conference with an ALICE Scientist and discuss their findings, the ALICE experiment and the Quark Gluon Plasma Physics.	Teachers take care of the technical requirements needed to conduct the live video-conference. They make sure that they have made a good summary of the students' questions before the videoconference.	
Phase 6: **COMMUNICATE:** students communicate and	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process.	Students organize in small groups and coordinate their results as well as further material to create a video which demonstrates:	Teachers help students employ their creativity and summarize their results in a motivational video in which	Students may use drawings, photo or video collages,

justify explanation	Such communication is crucial to an *ethical* approach to working scientifically.	1. Their experience after interviewing a scientist and following the path real researchers do in a large scientific infrastructure to understand how Nature works. 2. The scientific inquiry procedure they followed to understand the Quark Gluon Plasma detection at CERN. 3. Their analysis' results. The videos should be no longer than 1 minute. The target audience will be the general public, thus the students should not speak technically, but in a more generic way.	they speak of their experience and convey their excitement to the viewer.	handmade exhibits to aid them communicate their experience.

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students produce their videos and watch them in the classroom Students answer some questions on the Physics of strange particle decays as well as their active participation in the scientific research process.	Teachers facilitate the procedure of learning data acquisition from the students' discussions.	

6. Additional Information

All relevant companion resources and activities can be found in the dedicated online community of the CREATIONS portal http://portal.opendiscoveryspace.eu/community/alice-experiment-cern-848059

7. Assessment

The student motivation and creativity will be monitored using dedicated evaluation questionnaires developed by the CREATIONS consortium before and after the completion of the activity The content knowledge will be monitored throughout the lesson through dedicated questions and exercises which are done in a hands-on fashion.

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8. Possible Extension

After having obtained the desired knowledge and analytical skills, students can engaged in Large Scale Analysis procedure followed by the ALICE Masterclass. In this framework, students will study thousands of heavy ion collision events, verify the existence of Quark Gluon Plasma and connect with other schools to compare their results. For further information, the reader can visit this link: http://portal.opendiscoveryspace.eu/edu-object/alice-masterclass-webpage-848062 .

Students can use their videos in order to organize a short outreach event for their school with which they will explain to the audience how research is done at CERN as well as what was the scope of their research and present their results.

9. References

- http://alice.physicsmasterclasses.org/MasterClassWebpage.html
- http://alice.physicsmasterclasses.org/InstituteInstructions2015.pdf
- http://alice.physicsmasterclasses.org/alice-exercise-en-2013.pdf
- http://portal.opendiscoveryspace.eu/community/alice-experiment-cern-848059
- P.Foka, M.Janik: "ALICE MasterClass on Strangeness" , EPJ Web of Conferences, Volume 71,2014, 2nd International Conference on New Frontiers in Physics: https://doi.org/10.1051/epjconf/20147100057

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D3.2.41 Einstein Meets Creativity

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Emmanuel Chaniotakis (EA)
Code:	D 3.2.41.	**Contributors:**	
Version & Date: v1. 26/5/2017		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics\ Theory of Relativity\ Mass-Energy Equivalence and applications

1.2 Type of Activity

In school activity through which students are introduced to the scientific context of Einstein's famous equation : $E=mc^2$ in an artful fashion. Students get introduced for the first time in the Special Theory of Relativity, verify for themselves Einstein's mass energy equivalence through the paradigm of nuclear fission and explore Einstein's scientific, cultural and societal contributions through creative writing.

Duration

6 hours

1.3 Setting (formal / informal learning)

Formal

1.4 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Arts based aiming to have students communicate science through creative writing.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

The progress of Science in the field of High Energy Physics and Cosmology during the last century has provided humankind with new insight in the workings of Nature from sub-nuclear to cosmological scales. Despite the large visibility of such major scientific discoveries through the media and the press, the school curriculum has been left behind, excluding modern science and teaching physics that date before the 20th Century. Students are not able to comprehend the results of cutting edge research and educators are in their vast majority not in a position to answer students' questions which are sparked by their natural curiosity. This results in students' decrease of interest in science and in the prospects of following a scientific career, and a drop in educators' confidence and self-esteem.

Numerous efforts have taken place aiming to bridge this gap and bring Nobel Prize worthy Physics in the Classroom. To bridge the gap of Modern Physics with the Curriculum, introducing the Modern Worldview of Physics to high-school students should begin from the fundamental theoretical discoveries as was the Theory of Special Relativity and Quantum Mechanics, which constitute the natural successor of the Classical Physics topics discussed in the classroom.
In this framework, Einstein-Meets-Creativity Demonstrator aims to introduce students in Einstein's Special Theory of Relativity and its most famous equation:
"$E=mc^2$" in an artful and creative fashion.

To probe the students' conception about how scientists work, students will be exposed to Einstein's life and achievements and learn about the value of creativity and inspiration in the course of scientific inquiry. Furthermore, students get to look beyond the Scientific value of Einstein's Theory of Relativity and discover its cultural and societal impact, thus bringing up the topic of the Scientist's responsibility. In this framework, students will employ creative writing and put their imagination into action by placing themselves in Einstein's shoes and following his path, discoveries and decisions through time. Finally this approach will help students understand the impact of culture to the scientist's approach as well as the cultural impact of the scientist's work.

2.2 Added Value

- Students explore one of the most fundamental theories of Modern Science.
- Students study the impact of Modern Science in Human Civilization by discussing nuclear energy.
- Students combine scientific inquiry with creative writing to explore Science and Responsible Research and Innovation examining the actions and life of the most iconic Scientists of the 20th century.
- Application of IBSE in the classroom.
- Establishment of scientific thinking.
- Engagement in the role of creative writing according to the pedagogical framework of CREATIONS.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

Students become 'young researchers' and explore cutting edge physics from their school classroom. The students to learn how to employ interactive simulations in order to draw scientifically correct conclusions.

The domain specific objectives of this Demonstrator are:

8. The students to understand the basic principles of the Special Theory of Relativity.
9. The students to understand the meaning of $E=mc^2$ and learn about its applications.
10. The students to learn the basic principles of creative writing.
11. Introducing modern physics at the high school.
12. Employing creative writing to investigate the societal, scientific, spiritual contributions of Einstein, and the responsibility of the scientist in the framework of RRI through creative writing.
13. Connection of Science with Literature.

3.2 General skills objectives

4 Students will learn how to work collaboratively to produce a scientifically valid fictional story through creative writing.
5 Students will learn how to use virtual labs and simulations in order to perform a scientific inquiry.
6 Students develop skills necessary to do scientific inquiry.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator combines scientific inquiry with creative writing. Students investigate the Special Theory of Relativity and understand the Science behind Einstein's most famous equation: $E=mc^2$ using a virtual learning environment enriched with interactive simulations. Students will investigate the impact of Einstein's theory to the world and will employ creative writing in order to communicate their ideas on the 20^{th} century's most iconic scientist's course of thought and the responsibility of the scientist towards the society .

4.2 Student needs addressed

Students should be familiar with the terms: Mass, Energy, Velocity, momentum. Students should be familiar with units of energy and mass as well as unit conversions. Students should have a basic knowledge about the structure of the atom. A basic knowledge of chemical reactions is desired. The scientist's culture as a factor which influences scientific approaches is investigated.

5. Learning Activities & Effective Learning Environments

2 Question-eliciting activities

- Introductory material and questionnaire addressing the basic needs of the exercise will be offered to the students to explore before the beginning of the exercise.
- Introductory lecture about the special theory of relativity accompanied with video.
- Introduction to creative writing.

3 Active investigation

- Introduction to the general ideas of the Special Theory of Relativity.
- Introduction to creative writing.
- Investigation of Einstein's famous mass-energy relationship using a virtual learning environment.
- Distribution of students in groups and creation of a short fictional story per group based on Einstein's life, science and decisions.

Science topic: Physics \ Special Theory of Relativity Class information Year Group: 2nd and 3rd year of Senior High School. Age range: 15-17 Sex: both Pupil Ability: Basic computer usage required	Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In a computer laboratory and a classroom. *Health and Safety implications?* None *Technology?* *Teacher support?* The teacher will provide the students with preliminary material and is advised to discuss with them before the beginning of the activity. The relevant material can be found in this online virtual community: http://portal.opendiscoveryspace.eu/community/einstein-meets-creativity-847255
Prior pupil knowledge: Students should be familiar with the terms: Mass, Energy, Velocity, momentum. Students should be familiar with units of energy and mass as well as unit conversions. Students should have a basic knowledge about the structure of the atom. A basic knowledge of chemical reactions is desired.	

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Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* Students become 'young researchers' and explore cutting edge physics from their school classroom. The students to learn how to employ interactive simulations in order to draw scientifically correct conclusions. The domain specific objectives of this Demonstrator are: The students to Understand the basic principles of the Special Theory of Relativity. The students to understand the meaning of $E=mc^2$ and learn about its applications. The students to learn the basic principles of creative writing. Students will learn how to work collaboratively to produce a scientifically valid fictional story through creative writing. Students will learn how to use virtual labs and simulations in order to perform a scientific inquiry.

Assessment	**Differentiation**	**Key Concepts and Terminology**

Content knowledge assessed by questions and exercises during the course of the activity. Student creativity and science motivation assessed through a dedicated pre-post questionnaire.	As this activity combines STEM with Literature, it can attract students with both linguistic and STEM orientation and through their collaboration help both student categories excel in both fields.	Creative Writing, Responsible Research and Innovation, Theory of Relativity, Mass –Energy equivalence. **Science terminology:** Mass-Energy equivalence, Nuclear Fission, Chain reaction, Nuclear Reactor. **Arts terminology:** Creative writing
Session Objectives: This demonstrator combines scientific inquiry with creative writing. Students investigate the Special Theory of Relativity and understand the Science behind Einstein's most famous equation: $E=mc^2$ using a virtual learning environment enriched with interactive simulations. Students will investigate the impact of Einstein's theory to the world and will employ creative writing in order to communicate their ideas on the 20th century's most iconic scientist's course of thought and the responsibility of the scientist towards the society. The objective is for students to develop both their scientific skills as well as linguistic skills and combine them to produce a science based creative story. The link to the online activity can be found here: http://portal.opendiscoveryspace.eu/edu-object/einstein-meets-creativity-1-mass-deficit-and-nuclear-fission-847281 The link to the "Einstein Meets Creativity" Online community with the relevant resources and guidelines can be found here: http://portal.opendiscoveryspace.eu/community/einstein-meets-creativity-847255		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	Students get introduced to the Special Theory of Relativity and discuss the equation $E=mc^2$	Teachers make sure that they have a computer lab with internet connection and a projector. The teachers have already made a short introduction to the students concerning the theory of relativity, and have already discussed with the students the prior knowledge needed in order to carry out the demonstrator.	
Phase 2: **EVIDENCE:** students give	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as	Students form a research question about the meaning of mass-energy equivalence,		

priority to evidence	practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	and through a tour to the theory of chemical and nuclear reactions they explore the equation using the paradigm of nuclear fission. Then students apply the conservation of energy and the conservation of mass principles on a given fission reaction.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	The students calculate the masses of the reactants and the products of the participating nuclei as well as the energy release of the fission reaction. They observe the results and discuss. Using Einstein's theory of Special Relativity and the mass-energy equivalence, they calculate the nuclear mass deficit and connect it to the emitted energy. They verify the mass-energy equivalence.	The teachers, having already ensured the proper functionality of the technical infrastructure, closely monitor and guide students throughout their exercise. Students should work in groups of 2-3 per computer.	

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students understand that the law of conservation of energy and the law of conservation of mass don't apply individually in the subatomic scales but together due to relativistic effects. They watch videos which explain this effect and its applications to real world phenomena.	The teacher should help students interpret the results.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students see the following video concerning the development of the atomic bomb: https://www.youtube.com/watch?v=sc2XnvSN2HY The students read about Einstein's letter to President Roosevelt concerning the		

		development of the Atomic Bomb by the USA. http://www.atomicheritage.org/history/einstein-letter-1939 The letter: http://www.amnh.org/exhibitions/einstein/peace-and-war/the-manhattan-project/ A discussion is stimulated on concerning the responsibility of the scientist with respect to society.		
Phase 6: **COMMUNICATE:** students communicate and	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be	The students get introduced to creative writing techniques. Then, they divide in groups	In this part the Physics teacher could work together with a Language teacher in order to introduce students	The students get introduced to

justify explanation	*immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	and are asked to write a fictional story up to 1500 words long, based on facts and science related to $E=mc^2$ before and during World War 2. In the fictional story, the main character could be either Einstein himself, or another fictional character. The story should include the $E=mc^2$ equation at least once in the document.	properly to creative writing. A cooperation with a historian would be also advisable in terms of investigation of the historical context of Einstein's big discovery and his subsequent indirect engagement with the atomic bomb. Some basic guidelines on creative writing can be found in this link: http://www.writerstreasure.com/creative-writing-101/ The story could be purely fictional, based on "what if's". The teacher makes sure to divide students in groups in which there are students inclined both in science and	creative writing techniques. Then, they divide in groups and are asked to write a fictional story up to 1500 words long, based on facts and science related to $E=mc^2$ before and during

			in literature. To carry out the creative writing, the teacher can provide the students with alternative concepts, keeping in mind however, that there must be a reference to Einstein and the mass-energy equation. For further inspiration the teacher could present a documentary about Einstein's life and works to the students: https://www.youtube.com/watch?v=NyK5SG9rwWI	World War 2. In the fictional story, the main character could be either Einstein himself, or another fictional character. The story should include the $E=mc^2$ equation at least once in the

				documen t.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students present their creations and discuss among themselves as well as with their teachers about the scientific and historical context of their story.		

6. Additional Information

Additional information concerning the companion resources needed for the completion of this activity can be found in the dedicated CREATIONS online community:

http://portal.opendiscoveryspace.eu/community/einstein-meets-creativity-847255

These links present the films based on which students will work in the creative writing session: https://www.youtube.com/watch?v=NyK5SG9rwWI
http://www.imdb.com/title/tt5673782/?ref_=fn_al_tt_1

7. Assessment

The student motivation and creativity will be monitored using dedicated evaluation questionnaires developed by the CREATIONS consortium before and after the completion of the activity The content knowledge will be monitored throughout the lesson through dedicated questions and exercises which are done in a hands-on fashion.

8. Possible Extension

Students could study further the life and works of Albert Einstein and or other scientists of their time and following the same paradigm as the one presented in this Demonstrator, write a fictional story about them. This could also work as preliminary material to be transformed into a scenario for a theatrical display (for further information please visit the Learning Science Through Theatre Online Community: http://portal.opendiscoveryspace.eu/community/learning-science-through-theater-841279).

The creative writing of a science topic and personality could be also employed in the framework of a national or international competition.

- **References**
  http://einsteinpapers.press.princeton.edu/
- http://www.alberteinsteinsite.com/
- A. Einstein, 1905: "Does the inertia of a body depend on its energy-content?", https://www.fourmilab.ch/etexts/einstein/E_mc2/e_mc2.pdf
- Basic Guidelines for Creative Writing:
  http://www.writerstreasure.com/creative-writing-101/
- P. Harris, University of Sussex: "Special Relativity"
  https://web.stanford.edu/~oas/SI/SRGR/notes/srHarris.pdf

D3.2.42 The LHC Tunnel

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Emmanuel Chaniotakis (EA)
Code:	D 3.2.42.	**Contributors:**	Giannis Alexopoulos (EA)
Version & Date: v1. 24/5/2017		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

High Energy Physics at CERN

1.2 Type of Activity

This is a student activity taking place in both formal and informal settings, promoting the connection of school and research center. Through this activity students learn about CERN through an interactive exhibition, the "Interactive LHC tunnel" and investigate: i) the physics of high energy proton collisions and their detection in a playful fashion; ii) the Higgs mechanism through an interactive experience. Activity can take place both in local and in national level.

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

Formal (classroom) and informal (research center).

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Arts based.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

- Understanding advanced scientific topics beyond the reach of school curricula in a playful and engaging fashion

In order to understand Nature and the Laws governing our Universe, Modern Science has developed tools and techniques of sophistication far beyond the reach of school curricula. Modern discoveries are able to answer questions such as "What are we made of?", "What is the nature of mass?", "How did the Universe look like during its infancy", which were once in the realm of Philosophy and speculation. Today, these questions can be quantified and answered in cutting edge experiments, thus expanding the boundaries of human comprehension far beyond our everyday practice. In order to organize and conduct the experiments needed to verify such hypotheses, scientists form international collaborations consisting of thousands of scientists and engineers and build gigantic research infrastructures dedicated to the pursuit of fundamental knowledge. Such an international, multicultural research infrastructure is CERN, with experiments ran by thousands of scientists aiming to discover the most fundamental laws of the Universe with unprecedented accuracy.

Students are exposed to these scientific breakthroughs through media such as TV, newspapers, blogs or social media. However, the knowledge and skills needed to be able to comprehend the science behind these discoveries, are far beyond the reach of the school curricula. As a result, dedicated outreach activities have been developed by leading organizations involved in scientific research, science education and outreach, in order to bring students in touch with modern scientific research culture, demonstrate to them cutting edge scientific achievements and cultivate the skills needed in order the students to become 'little researchers' and explore on their own the fascinating world of modern science.

In this framework, the "LHC tunnel" demonstrator employs an interactive ICT-enhanced exhibit created by CERN's media-lab in order to bring students closer to the scientific endeavours taking place at the world's largest particle physics laboratory. By having students to "kick" protons in order to produce simulated high energy proton collisions and observe the products of them and by having students experiment and perform in a visualization of a world with and without the Higgs boson, their interest in science is sparked and the complex subatomic phenomena are addressed in a fashion understandable by them.

2.2 Added Value

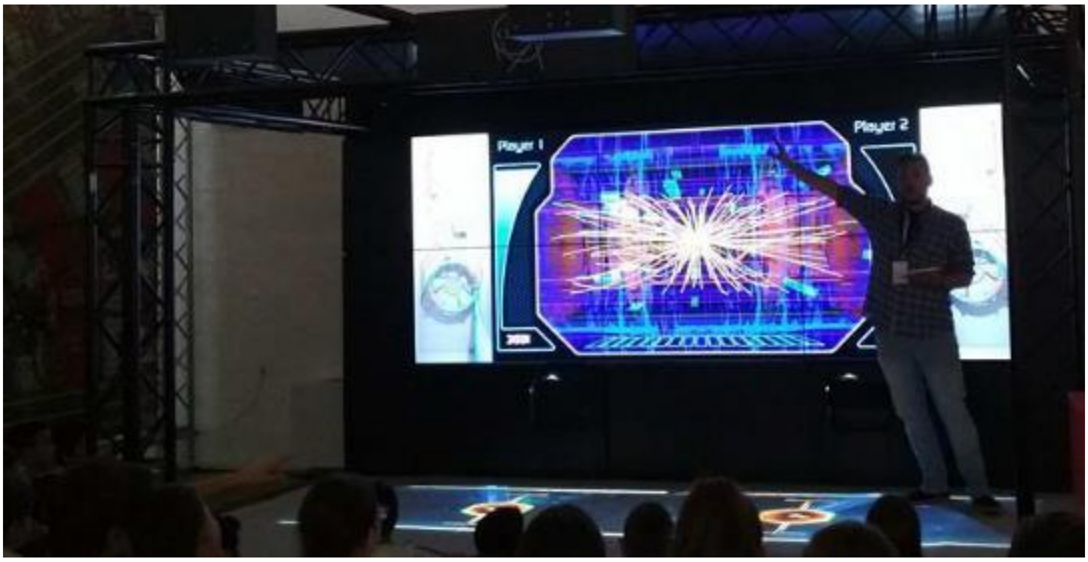
- Students learn about cutting edge research at CERN in a hands-on and minds-on fashion.
- Students divide in small groups and investigate the physics of the proton-football they conduct.
- Students learn Physics within and beyond their school curricula and thus get inspired on science in general.
- Development of analytical thinking.

3. Learning Objectives

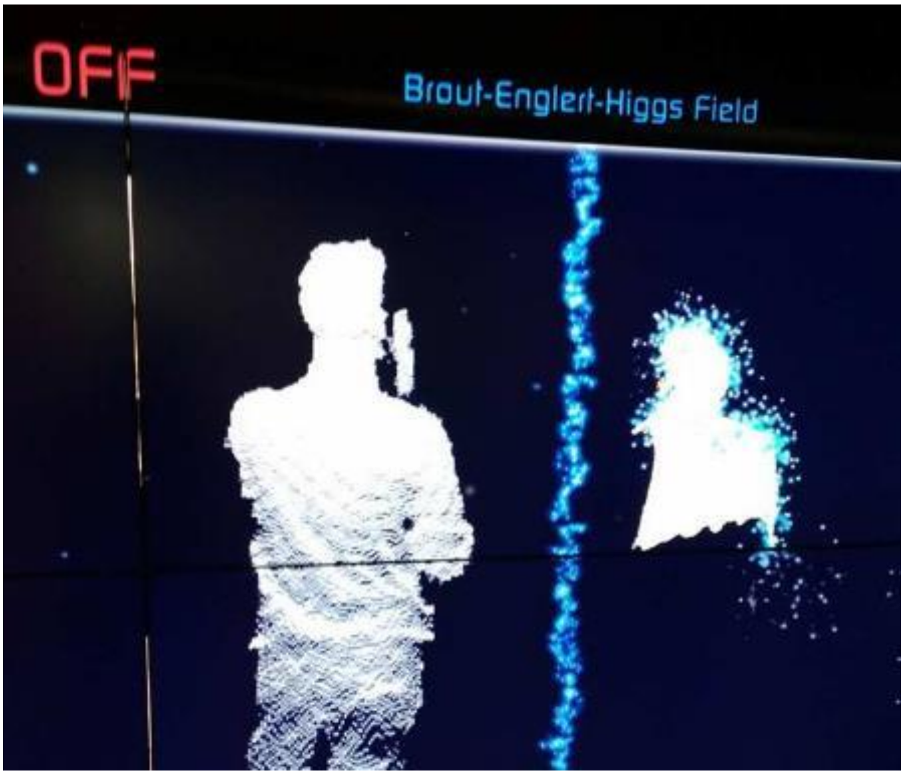
3.1 Domain specific objectives

Concepts like "the influence of Higgs Field on matter" and "particle acceleration and collision" can lead to explanations which are quite often hard to understand and even harder to retain. By immersing students in a fully interactive gaming experience, the Interactive LHC Tunnel touring exhibition manages to bridge the gaps between science education, interactive media and information visualization, creating an entertaining and memorable tool for learning.
Using Kinects to detect users, and projecting images on the floor and on a video wall, we can create different learning experiences in a variety of subjects.

The learning objectives of this demonstrator are:

1. The students to understand the principles of particle acceleration, collision and detection at CERN. This is achieved through a gaming experience called "Proton Football": Students become particle accelerators themselves by kicking protons. By varying the force of their "kick" they vary the energy offered to a proton and thus the collision energy of the protons. The collision energy in turn defines the multiplicity of particles produced in a particle collision. Furthermore, students learn about Einstein's famous $E=mc^2$ equation and learn that higher collision energies can result in the production of heavy particles. Finally, students learn about components of a modern particle detector including the tracker and the calorimeter and learn how these detectors can provide us with information regarding the collision process and products.


2. The Higgs Boson, discovered by scientists at CERN, is one of the keys to understand why the universe is the way it is. In Higgnite, a kinect-based mixed environment, the user becomes a particle, which can hop between an area where the Higgs Field is absent, and another where it will interact with the Higgs Field, thus gaining mass.



3.2 General skills objectives

- Students learn to apply teamwork and analytical thinking in order to connect the results of their game with the scientific output of their achievements.
- Students learn to control variables and observe the results.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is a hands-on activity aiming to introduce the scientific culture of large research infrastructures such as CERN to students in a playful and engaging fashion.

4.2 Student needs addressed

In this activity, students develop their knowledge on scientific issues beyond the reach of their school curricula. They develop creative skills, critical thinking and learn how a scientist thinks by doing their own inquiries based on the IBSE model.

5. Learning Activities & Effective Learning Environments

2 Question-eliciting activities

- Introductory material addressing the basic needs of the exercise will be offered to the students to explore before the beginning of the exercise.
- Lecture about elementary particles, CERN, LHC will be delivered by experts.
- Discussion/question/answer session with the students and teachers and experts.

3 Active investigation

- Introduction to the features of the LHC Tunnel exhibition.
- Introductory lecture about CERN, LHC and its experiments.
- Proton football and introduction to aspects of particle acceleration, collision and detection.
- Introduction to the Higgs boson through the artistic impression of Higgnite
- Students choose one fundamental physics property (electric charge, mass, spin) and create an artwork inspired by Higgnite to demonstrate how they believe the world would be without these properties.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: High Energy Physics. Class information Year Group: Sixth year of Primary school to Third year of Senior High School. Age range: 12-18 Sex: both Pupil Ability: Team work, analytical thinking	Materials and Resources: The setup of the LHC tunnel interactive exhibition needs to be available for the implementation of this demonstrator. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In informal settings (such as science festivals) or formal settings (schools). *Health and Safety implications?* None *Technology?* ➢ *Teacher support?*. The relevant material can be found in this online virtual community: http://portal.opendiscoveryspace.eu/en/community/lets-explore-lhc-tunnel-849923
Prior pupil knowledge: The students involved in this activity need to have basic knowledge of the principle of conservation of energy and momentum and its applications in collisions. Basic knowledge of phenomena related to special relativity as well as the structure of matter are desired.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* Using Kinects to detect users, and projecting images on the floor and on a video wall, we can create different learning experiences in a variety of subjects. By the end of the lesson, the students should be able to understand the mission of CERN, the principles of particle acceleration, collision and detection as well as the influence of the Higgs field on matter.		
Assessment Content knowledge is assessed through specific questions and exercises throughout the in-class activity and creativity as well as science motivation are assessed through pre-post questionnaires.	**Differentiation** The activities described in this demonstrator refer to very advanced scientific concepts and the attempt to bring them in the classroom. As a result they have specific content knowledge requirements. Variants of these activities including a presentation and creative expression of students combined with a virtual visit can be performed by more students without tight content knowledge restrictions.	**Key Concepts and Terminology** Proton football, higgnite, Kinect, angry birds, augmented reality. **Science terminology:** Proton, quark, Higgs, CERN, LHC, particle Collision, particle detection, mass, energy, particle multiplicity, cosmic ray, speed of light **Arts terminology:** Graphic display of particle collisions, Artistic impression of Higgs field

Session Objectives:

Concepts like "the influence of Higgs Field on matter" and "particle acceleration and collision" can lead to explanations which are quite often hard to understand and even harder to retain. By immersing students in a fully interactive gaming experience, the Interactive LHC Tunnel touring exhibition manages to bridge the gaps between science education, interactive media and information visualization, creating an entertaining and memorable tool for learning.

In the end of the activity, students will create a their own artwork- based on the Higgnite example- demonstrating how they believe that the Universe would be like if one of the following fundamental particle properties didn't exist (electric charge, mass, spin).

For a demonstration of the LHC interactive tunnel exhibition, please see the following link: http://portal.opendiscoveryspace.eu/en/community/lets-explore-lhc-tunnel-849923

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	Students get introduced to key concepts and ideas in elementary particle physics and particle collisions. They observe the introductory video of CERN and discuss about the size, the mission and the components of the	The teacher introduces students to the mission and vision of CERN. The teacher can consult this video: https://www.youtube.com/watch?v=328pw5Taeg0 Furthermore, they can visit:	

	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	great particle physics laboratory. They wonder: - why do we need such a big experimental facility to measure the very small? - how can we extract, bunch and accelerate such small particles at speeds close to the speed of light and then have them collide? - what is the benefit of research at CERN? Why is it important to study particle collisions?	https://home.cern/about for extra details. Students should also have a prior knowledge regarding the constituents of matter at an introductory level https://www.youtube.com/watch?v=7WhRJV_bAiE In order to be able to discuss the impact of CERN to society, the teacher could visit this link for preparatory material: https://kt.cern/funding/kt-fund	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students divide in groups of two and play "proton football": a Kinect based interactive activity in which the students can kick a proton emulating the procedure of proton acceleration. When the "protons" of the two students	The teacher describes the path of a proton beam towards its collision and briefly introduces students to the concept of particle detectors. Then the teacher launches the proton football game.	

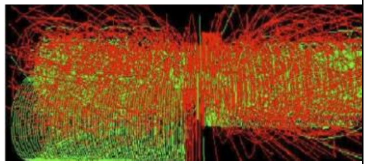
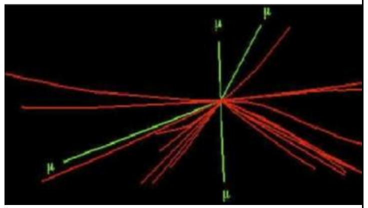
		collide, they observe the results of a simulated collision in a monitor next to them. The students explore the relationship between the force of their kick and the energy of the simulated protons and observe the output in the simulated detector.	To introduce students to particle collisions and detectors, the teacher can prepare using this introductory material: http://www.particleadventure.org/accelerators-and-detectors.html The teacher acts as a mentor and explains to the students the components of a modern particle detector. They draw the students' attention to the fact that as they kick harder, the proton energy increases and thus the collision energy increases.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	The students measure the number of particles produced with respect to the sum of proton energies.	The teacher asks the students what happens when collision energy increases. The students need to observe	

		To count particles more easily, students can use the "Angry Birds" visualization option.	the monitor and see for themselves that the number of produced particles increases as the proton energy increases. http://www.particleadventure.org/colliding_beam.html The teacher asks the students the question: "Since we collide two particles, why do we observe way more after the collision?" This will trigger a discussion regarding the famous mass-energy relationship of Einstein: The energy produced by the particle collision becomes mass and therefore more particles can be produced during the collision. For further information on this, the teacher can visit this	

			link: http://portal.opendiscoveryspace.eu/sites/default/files/emc2_proof.pdf and the orientation section of this educational scenario: http://tools.inspiringscience.eu/delivery/view/index.html?id=b751e977827743e390c2fd4df0ef46af&t=p	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Part 1:The students make a brief presentation regarding their explanation of the proton-proton collision based on the evidence they collected. Part 2: Students discuss with their teacher about how they could detect a new particle using a particle detector like those of CERN. They discuss the difficulties of detecting a rare	Part 1: the teacher encourages the students to make a short presentation in the class explaining what they have learned so far. Part 2: The teacher explains to the students that the LHC produces about 100.000.000 proton collisions per second. These collisions produce particles that may be more massive than the proton, if the energy produced by the	

		Physics process taking place during a particle collision, such as the production of a Higgs boson. Part 3: The students wonder what is the importance of observing a new particle such as the Higgs boson.	collision is enough to create a particle of their mass. The Standard Model of Particle Physics (http://www.particleadventure.org/standard-model.html) provides the "selection rules" that determine whether a new particle will be produced, how it will be produced, how often it will be produced and how it decays. Of course we believe that there is Physics beyond the Standard Model which may result in new observable phenomena that we can tackle in the LHC. The production of the Higgs particle (https://archive.nytimes.com/www.nytimes.com/interactive/2013/10/08/science/the-higgs-	

			boson.html?WT.z_sma=SC_WIT_20131008&_r=3&smid=fb-nytimes#/?g=true&higgs2_slide=4 , https://www.youtube.com/watch?v=joTKd5j3mzk), a particle that was searched for almost 50 years before it was detected at CERN in 2012 is an example of a very rare process. **For every 10^{13} protons that collide, 1 Higgs particle is created** and spontaneously decays to pairs of photons (https://www.youtube.com/watch?v=51XK4YeNEn8) , or to 4 leptons (μ-μ+e-e+, μ-μ+μ-μ+, e-e+e-e+) or other signatures. Observing it will be like searching for a needle in a haystack! To observe the	

			decay pattern of the Higgs, scientists need very powerful selection algorithms which will be able to transform an event display looking like this:  to something like this:  Part 3: The teacher explains to the students that the Higgs particle is responsible for the property of mass. The teacher can show this video to the students: https://www.youtube.com/watch?v=joTKd5j3mzk in order to understand the	

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			concept of interaction with the Higgs field to produce mass.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students wonder how our world would be without the property of mass – thus, without the existence of the Higgs boson. They use Higgnite in order to experiment and perform in an artistically presented environment displaying the world without the property of inertia (Higgs field off) and with inertia (Higgs field on).	The teacher introduces students to the Higgnite mode of the LHC Tunnel, making sure that no more than 4 students at a time visit it. The teacher should explain to the students that in a world without a Higgs field, no particle would have mass, therefore everything would move with the speed of light and no stable structures could be made (such as atoms). Even the elementary particles themselves would be fundamentally different than those we observe.	**The artistic analogy of a student to a particle through the Higgnite mode of the LHC tunnel.**

			The on-off version of the Higgnite mode displays what a particle would "feel" in an abstract and artistic way in a world with inertia and without. The projection of the student on the monitor through the Kinect detectors represents a particle.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Part 1: Students make a short video of their experience and present it to their school. Part 2: Inspired by the way that Higgnite metaphorically explains how the world would be with or without the property of mass, they create their own artworks to express how they feel the world would be like if there	Teachers help students employ their creativity and summarize their results in a motivational video in which they speak of their experience and convey their excitement to the viewer. With the help of an arts teacher, the students are guided to create an artwork which would describe	Video presentation. Creation of artwork

		were no other fundamental physics properties such as electric charge or spin. Students present their videos and artworks in a dedicated "LHC day" at their school.	abstractly how the world might be like if properties such as the electric charge didn't exist.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students discuss among themselves and with the teacher and reflect on the feedback they obtained during the communication phase.	Teachers facilitate the procedure of learning data acquisition from the students' discussions.	

6. Additional Information

All relevant companion resources and activities can be found in the dedicated online community of the CREATIONS portal http://portal.opendiscoveryspace.eu/en/community/lets-explore-lhc-tunnel-849923

7. Assessment

The student motivation and creativity will be monitored using dedicated evaluation questionnaires developed by the CREATIONS consortium before and after the completion of the activity The content knowledge will be monitored throughout the lesson through dedicated questions and exercises which are done in a hands-on fashion.

8. Possible Extension

This activity can be coupled with an artistic intervention as described in the Cultural Collisions community (http://portal.opendiscoveryspace.eu/node/848012) or the Art@CMS community (http://portal.opendiscoveryspace.eu/node/846962). Having obtained a sound introduction regarding physics at CERN, students can perform mini-masterclasses as described by the HYPATIA demonstrator (http://portal.opendiscoveryspace.eu/node/847063).

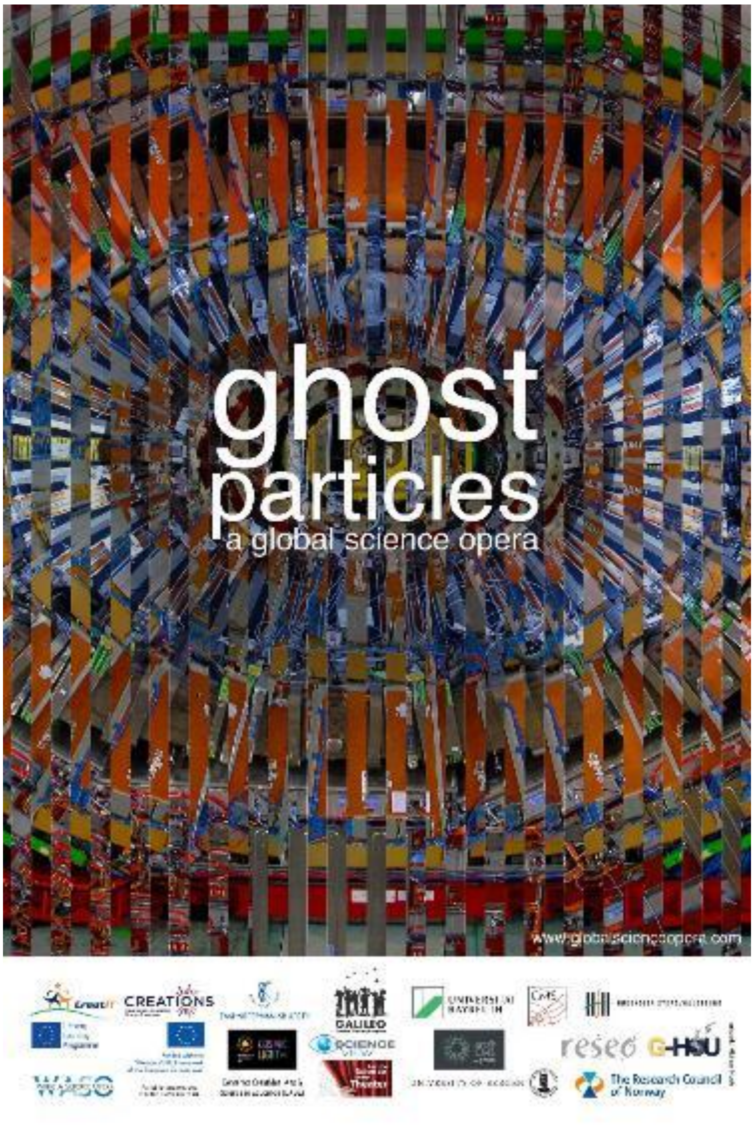
9. References

- http://portal.opendiscoveryspace.eu/en/community/lets-explore-lhc-tunnel-849923
- http://cern.ea.gr
- http://medialab.web.cern.ch/content/lhc-interactive-tunnel

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.43 Global Science Opera (GSO)

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Oded Ben-Horin (HSH), Sofoklis Sotiriou (EA), Petros Stergiopoulos (EA) Janne Robbestad (HSH)
Code:	D 3.2.43.	**Contributors:**	Menelaos Sotiriou (NKUA), art@CMS
Version & Date:	1.0 / May 9th, 2016	**Approved by:**	NKUA



1. Introduction / Demonstrator Identity

1.1 Subject Domain

The Global Science Opera (GSO) annual production in 2016 ("Ghost Particles") focuses on particle physics, and specifically the particles photon, neutrino and Higgs boson. The opera communicates scientific knowledge about these particles as well as some of the creative processes that led up to our understanding of them (e.g. Wolfgang Pauli's postulation of the Neutrino particle in 1930 and the process that ensued). Through both science and arts education activities and a virtual visit to CERN, pupils engage with inquiry-based activities.

Ghost Particles rehearsal for European Opera Days (EOD), Holland (May, 2016)

1.2 Type of Activity

GSO is a global, trans-disciplinary creative education initiative made possible through digital interactions. It is a network of scientists, art institutions, schools, universities, in all of the inhabited continents. It exists at the meeting point of science and art, of pupils and scientists, of research and practice, and of all human cultures. GSO envisions, creates, produces and performs educational operas by and for a global community through real-time live streaming. Each school takes part in a local implementation which is also part of the international effort.

1.3 Duration

The process of creating a GSO production lasts for approximately 10 months. During this time, teachers in the various countries choose to dedicate time according to their capacities, and their roles in the opera (e.g. performing countries usually dedicate more time than others). The premier opera performance (scheduled for November 19th, 2016) is expected to last for 5 hours including sound checks, general rehearsal, and actual performance.

1.4 Setting (formal / informal learning)

GSO is open to all kinds of educational frameworks. Most of the performing parties are schools which have integrated the GSO into their activities (e.g. the Premier Academy in Milton Keynes, England). There have also been examples of other types of institutions, such as universities (e.g. the Dance company of the University of Antofagasta in Chile), or groups of disabled pupils coached by a theater school (e.g. Speel je Wijs, Holland).

The Serbian Music and Science ensemble, "Galactic Echo" is composing music for the "Ghost Particles" opera

1.5 Effective Learning Environment

This demonstrator relates to the following categorization (please see CREATIONS D2.3 for further details):

- **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- **Communities of practice (web-based/physical)** aiming to develop a network of online communities and channels sharing multicast-activities inspired by science on national or international level.
- **Communication of scientific ideas to audience** addressing the need to establish settings in which learners will be enhanced to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.); promoting this way a dual channel of communication: a) reflective processes (self-engagement for scientific consistency and verification) and b) explicit elaboration of scientific ideas through interaction and 'extroversion'.

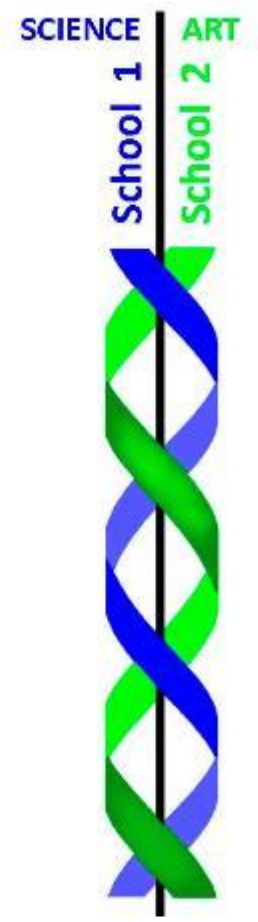
The GSO approach has been to communicate with "alpha-contacts" in each country, who thereafter engage institutions in their countries. For this reason, there has been a wide diversity in the approach to implementation, and to what effective learning environments represent.

- Global environment: Digital platform (Adobe Connect for meetings/rehearsals, and live-streaming for performance)
- Local environment: School, university, art institution or research center

2. Rational of the Activity / Educational Approach

2.1 Challenge

While GSO provides many opportunities, it also poses challenges in the areas of implementation, common learning goals across country borders in different continents and different age-groups, common understanding of arts education procedures, the definition of artistic quality in this context, and a disparity regarding technical means between schools in varying countries.



Relevance for RRI: A goal of the GSO is to facilitate **inclusion** of any and every pupil regardless of any circumstances. That leads to situations, though, in which some participating schools have barriers to participation due to lack of basic technological equipment. Due to its global character, many of the participating countries are not eligible for EU funding. Rather, in the long-term, the inclusion of these pupils must be based on a creative activity which can provide inclusion for many such schools. One approach to this is the development of a "Science Opera" app which will enable participation of whole communities of schools in the GSO. This app is currently being developed by students of the AP college in Belgium's European Project Semester (EPS), who will receive 20 ECTS for their effort. *Delivery time: Spring 2017.*

2.2 Added Value

GSO provides learning opportunities in which pupils from around the globe may cross-inspire and learn from and with each other. In addition to being a crowd-sourced collaborative creativity environment, it provides social and emotional settings during which pupils of various cultures, traditions, ages and religions, may explore together. GSO necessitates Possibility Thinking (see CREATIONS Deliverable 2.1), as it requires the invention of solutions for a variety of artistic, science education and technological procedures. Also, for school pupils, preliminary data has shown that the concept of "performing in front of the whole world" provides a growing opportunity. Several of the scenes in "Ghost Particles" are being created by educational institutions in more than one country together (e.g. Spain/Portugal, Greece/UK, Norway/Iran/Germany). In some cases (e.g. Australia/UK), continued collaboration has been established beyond the GSO production boundaries.

Relevance for RRI: Robbestad (2016) has proposed that the GSO's scope is fitting to the integration of concepts of eco-scenography, and thus communicating **sustainable** procedures with regard to materials used for the GSO's scenography of productions, and possible inspiring the thematic field of exploration in future productions.

3. Learning Objectives

3.1 Domain specific objectives

The domain in 2016 is particle physics. Due to the fact that GSO pupil ages vary from country to country, learning objectives must be defined locally by each school. Generally speaking, the objectives of the 2016 production have been to become acquainted with the particles photon, Higgs boson, Neutrino, with the discovery process of the Neutrino, with the research at CERN, and, through virtual visits to CERN, to engage in questions inspiring inquiry in this field (Chappell et al, 2016).

In arts education, the objectives are to learn school opera as a methodology, including specific skills and inquiry with the various included arts education domains (music, drama, scenography, light design, etc.).

"Firefly" is one of the main characters in the "Ghost Particles" opera

3.2 General skills objectives

The objective of skills may be seen as developing social and emotional skills, cognitive skills, and, especially, meeting points between these, within an international context. Creativity and critical thinking, both considered to be "21st century skills", may largely be said to occur in the interaction, and cross-fertilization between these groups of skills (OECD, 2015).

More specifically, learning across boundaries, inquiry spanning over more than one school collaboratively, and technological skills, may be seen to be part of the inquiry process exemplified by GSO.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to describe the GSO methodology for implementation, explore further its challenges and opportunities, receive rigorous feedback regarding this relatively new practice, and support its implementation within the CREATIONS project.

4.2 Student needs addressed

Needs addressed are the creation of a Living Dialogic Space within creative science exploration, and rigorous engagement with Possibility Thinking (see CREATIONS Deliverable 2.1).

5. Learning Activities & Effective Learning Environments

Due to its character, GSO exercises a flexible implementation, whereby several options are provided to the "alpha-contacts", from which they may choose to implement their participation.

Over the complete production, the complete GSO network simulates an "opera company" in which performers, composers, designers, scenographers, science educators, etc., collaborate to create an opera. There is therefore no "one size fits all" approach to the activity. Typically, though, a school will receive a scene in the opera, which they will write the libretto for following their exploration of the scientific theme at hand, and thereafter compose music for it, and perform that scene by video or online, as part of a global community.

1 In the Global Science Opera, the various opera scenes take place around the globe in real time

Science topic: particle physics **(Relevance to national curriculum)** **Class information** **Year Group: GSO is open to all grades. Most classes are 5th grade or higher.** **Age range: GSO is open to all ages. Most pupils are of age 10 and older** **Sex: both** **Pupil Ability: The scenario allows space for pupils of various abilities to participate. Each teacher is responsible for connecting the scientific theme to the level of his/her pupils, with a focus on science and/or art, according to the educator's specialization, yet all participate in both exploratory processes to various degrees. GSO is open to pupils with disabilities, and the Dutch team has focused on involving pupils with disabilities in the project.**	**Materials and Resources** ***What do you need?*** **This depends on the specific activity taking place in each school. Examples : Performers will need access to video and/or streaming facilities, as well as costumes. Composers need access to music lessons and instruments. All participants need access to high level scientific information, which is continuously in dialogue with scientists and science educators, and will achieve its highlight during the virtual visit(s) to CERN during the process.** ***Where will the learning take place?*** **Each class will decide this for themselves. Most learning will take place in the classroom, in a local arts institution, and during virtual visits to CERN.** ***Health and Safety implications?*** **These are not considerable.** ***Technology?*** **Yes. Taking part in the rehearsals and streaming (for countries performing live) involves access to internet.** ***Teacher support?*** **Both science and art teacher support is needed. In countries in which the GSO teachers belong to only one of these disciplines, GSO has encouraged making contact with teachers or professionals within the other discipline(s), or collaboration with one of the other teams in order to make up for the lacking capacity in that specific school/university.**

Prior pupil knowledge

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Individual session project objectives*:*
The GSO "Ghost Particles" scenario/production will be an opportunity for students to explore issues related to particles and their scientific qualities, and general acquaintance with the research at CERN, based on virtual visits (Alexopoulos, 2016) which will set the inquiry process for the opera in motion.
GSO is focused on science inquiry in a creative framework. In addition, science communication is also a major factor by allowing a scientific theme to inspire a multi-disciplinary artistic project's outputs. The complete process is guided by persons from within a variety of disciplines including both science and the arts. Characters, libretto, composition, stage design, costume, etc. will be studied by pupils and realized during the project.
The project will also allow students to interact and develop social and collaboration skills, thus experiencing how science can be a group activity and not only a solitary one: Individual, collaborative and communal activities for change. This takes place also within the added digital dimension, in which pupils take part in a "Global Classroom" with other pupils around the world.
Pupils will be introduced to the common creative impulses of science and the arts.
Specifically, the following aims are present:

- **Active participation in the negotiation of scientific concepts**
- **Developing creative skills based on the CREATIONS inquiry approach**
- **Understanding of scientific concepts and phenomena**
- **Scientific interconnection of science with aspects of art (students will undergo a multi-disciplinary artistic process which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).**
- **Developing a cross-country, multi-cultural spirit of friendship, cooperation and teamwork**
- **Digital competences and their social impacts**

Connecting the science classroom with research infrastructures

Assessment	**Differentiation**	**Key Concepts and Terminology**
The WASO Guidelines' Appendix 1 provides an evaluation plan for students who took part in the WASO project. This questionnaire includes questions about their level of enjoyment, level of difficulty, comparisons to more	*How can the activities be adapted to the needs of individual pupils?* This is up to the local teachers. GSO provides a framework which needs local adaptation. In the future, it will be possible to develop GSO's for a specific age group, with a tailor-made curriculum focus.	**Science terminology:** Higgs Boson, Photons, Neutrinos, Mass, Light, Big Bang, the Sun, Oscillations of Neutrino particles **Arts terminology:** 1) Aria: Solo song by one character. The plot's "action" is stopped to allow this character to express a certain emotion and inner feelings.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

traditional teaching methods, etc. **The issue of assessment of the artistic quality is relevant as well, especially with regard to GSO's outreach capabilities.**		2) Duet: Two singers, preferably each singing their own verse followed by a section in which they sing together. 3) Ensembles: Three or more singers 4) Choir: The choir can be used to "comment" during the other songs, or as simple choir pieces. 5) Overture: Instrumental (no voices) opening piece which sets the mood of the opera. 6) Interlude: Music performed between acts or scenes. 7) Recitative: "Spoken Song" which tells a story, and which propels the plot further by revealing action (what has taken place, what will take place, a secret, etc.). 8) Tableau– A dramatic activity in which a group of pupils are asked to physically construct an opera scene through body placement, facial expressions, and props 9) Various musical instruments
Session Objectives: **During this scenario, students will** **Explore the art@CMS website, and learn about modern research concerning the relevant particles (Neutrinos, Photons, Higgs Boson); Take part in a virtual visit to CERN; Experience musical, visual design, drama techniques as tools for the opera; be introduced to pupils from other countries.**		

Students will gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the Science Opera, accompanied by a continued exploration of the particles. The libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music. **Throughout the scenario, pupils will learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.**				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Generate and writes down words\ideas about Neutrinos, Photons, Higgs Boson, and shares with others in order to learn from their previous knowledge.	Activates previous knowledge in the fields of scientific exploration, and introduces particles by means of a virtual visit to CERN.	Begin cooperation with music/fine arts/drama/dance teacher(s) at your school in order to explore those subjects. Examples: experimenting with various musical instruments and drama techniques.

Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students compare their ideas to existing evidence. Take part in virtual visit to CERN.	Guide students to relevant evidence.	Comparing artistic ideas to other art-works, especially school art works created by pupils. Give preference to art projects inspired by scientific phenomena.
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse evidence and make conclusions regarding their own initiative.	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin creating and rehearsing the opera within the various arts disciplines (libretto, costumes, music, etc.)
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of scientific explanations, and sharing ideas with GSO schools in other countries	Guide students in their consideration of possibilities.	Continued production of original material (music, etc.), and opera rehearsals, and expanding awareness of what other GSO students are developing.
Phase 5: **CONNECT: students connect explanations to**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and	Ensure scientific quality with regard to explanations	Continued rehearsals, costumes making. Rehearsals may

scientific knowledge	origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	artistic ideas may cross-fertilize each other within the inquiry process.		take place with other countries at this stage.
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications.	Supports the communication process and the opera performance logistics	Opera performance locally and online (streaming)
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the scientific and artistic conclusions	Discuss the implications of a global collaboration with students	Reflection on the process, and collection of documentation of data from the GSO event to the extent possible / sharing experiences via social media.

6. Additional Information

Ghost Particles premier will take place on 19th November, 2016.

Website: www.globalscienceopera.com

7. Assessment

During your training workshop for teachers, you will be asked to assess the workshop. Please refer to the CREATIONS project website in order to learn more about assessment structures for pupils.

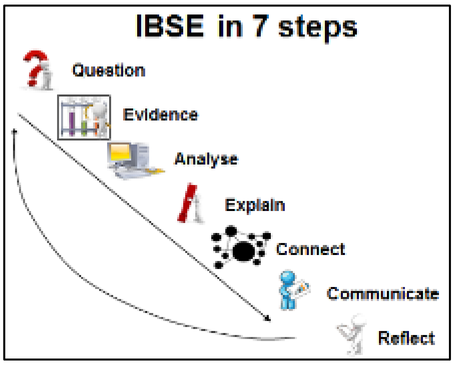
In assessing the GSO activities, it is important to consider the scientific content, the artistic content, as well as the creative environment of the activity as it emerges at the meeting point of science and art, with regard to the CREATIONS pedagogical principles (see CREATIONS D2.1).

The issue of assessment of the artistic quality is relevant as well, especially with regard to GSO's outreach capabilities.

To summarize, there is as of yet no standardized approach to assessing the process and outcome of a GSO production. It would seem as though the field of cross-analysis, in which emerging themes from e.g. science and arts, may be explored within one unified framework, would be a positive approach to pursue in this regard. Efforts are currently underway in this direction.

8. Possible Extension

The CREATIONS approach to inquiry has highlighted dialogue between science and the arts. Also, communal/community are a focal point. Within the scope of the GSO, it is possible to integrate these elements within the initiative's design to a greater extent. This entails bringing closer the various processes occurring in the different countries involved. Stergiopoulos (2015) has approached this by establishing a real-time interactive platform for music-making within the opera. The diagram above also expresses an attempt to unify a more homogenous process of "trading" between schools and across disciplines (Ben-Horin, 2015).



CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.44 Write a Science Opera (WASO)

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Oded Ben-Horin (HSH)
Code:	D 3.2.44	**Contributors:**	
Version & Date:	1.0 / May 27th, 2016	**Approved by:NKUA**	

Write a Science Opera (WASO): 2-day workshop for teachers aimed at school implementation of Science Opera on the subject of elementary particles.

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Subject domain may include all areas of STEM, as well as a multi-disciplinary approach to arts which includes visual arts, music, drama, lighting design, and more.

1.2 Type of Activity

Write a Science Opera (WASO) is a creative professional development approach to inquiry-based science and art education in which pupils of different ages, supported by teachers, artists and scientists, are the creators of an educational performance. This demonstrator relates to training for European teachers which can be realized in a school, community, arts institutions, etc.

WASO workshop with teachers from Belgium and Holland (2015)

1.3 Duration

This demonstrator describes a 2-day training workshop.

1.4 Setting (formal / informal learning)

WASO is open to all kinds of educational frameworks. Most of the activities thus far have involved formal learning settings, especially late-primary and early-secondary schools. The method is open to include informal learning environments.

1.5 Effective Learning Environment

This demonstrator relates to the following categorizations (see CREATIONS D2.3 for further detail):

- **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

The WASO training described here typically takes place with several teachers from a single school, or with several teachers from a municipality who converge in one school (or other institutions such as university) in order to take part in the training.

When realized in schools, the WASO learning environment is collaborative, creative and flexible. It includes much movement (e.g. drama exercises), and approximately halfway through the project the class is divided into groups to create an "opera company" (orchestra, PR group, singers, light specialists, etc.). This structure implies a non-typical classroom situation at times which resembles a "workshop" atmosphere, and in which unexpected questions and situations may arise, as the pupils begin to take charge of the learning process and the communication of that learning.

2. Rational of the Activity / Educational Approach

2.1 Challenge

WASO offers an inherently creative design which stimulates creativity in the Inquiry-Based Science Education (IBSE) setting. It thus responds to challenges in today's schools regarding the rate of uptake of IBSE, the strengthening of creative approaches to learning in schools, and the need for an intuitive engagement of social and emotional skills in the science classroom in order for the science classroom to become more engaging. In this specific demonstrator, the field of Particle Physics is explored.

2.2 Added Value

WASO provides learning opportunities in which pupils may cross-inspire and learn from and with each other in a creative school environment. In the proposed two-day workshop, teachers will gain techniques to support their ability to engage pupils in science inquiry in new, creative ways. Pupils will, during implementation in schools following the training workshop, be able to explore scientific questions through drama, music and visual arts. In this way they will gain access to the scientific material which is being taught from a large variety of perspectives.

3 Learning Objectives

3.1 Domain specific objectives

The scientific theme of this demonstrator is to explore elementary particles: photons, Higgs Boson, Neutrinos.

In the arts education domain, the objectives are to learn school opera as a methodology, including specific skills and inquiry with the various included arts education domains (music, drama, scenography, light design, etc.).

More specifically, teachers will learn how to guide their pupils so that they will be able to:

- Finalize and perform a multi-disciplinary artistic performance (school opera) which demonstrates and deepens scientific and emotional understanding of the star rotation scenario learning processes, supporting discipline knowledge in both the science and arts educational disciplines.

- Engage in activities which inspire curiosity around elementary particles; Explore musical, visual design, drama techniques as tools for the opera. *Note: Teachers may decide the science opera's theme before the project or allow pupils to choose the scientific theme themselves. Each approach has its advantages: In the case in which the teacher chooses the theme prior to the project, it will be possible to realize the project during a shorter time-span. On the other hand, pupils may experience greater ownership and agency if they are allowed to choose the opera's theme themselves. In both cases (teacher choice or pupils' choice) it is important and motivating that the pupils investigate their own questions connected to the chosen theme.*

- Gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the Science Opera, accompanied by a continued exploration of particles. Students will learn to create specific synopsis, libretto, composition, scenography, costumes for the Science Opera. Continued exploration of scientific topics. *The libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.*

3.2 General skills objectives

The objective of skills may be seen as developing social and emotional skills, cognitive skills, and, especially, meeting points between these, within an international context. Creativity and critical

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thinking, both considered to be "21st century skills", may largely be said to occur in the interaction, and cross-fertilization between these groups of skills (OECD, 2015).

Specific skills:

- Active participation in the negotiation of scientific concepts
- Developing creative and critical skills
- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art (students will undergo a multi-disciplinary artistic process which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- Developing a spirit of cooperation and teamwork
- Connecting the science classroom with research infrastructures
- digital competencies

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to describe the WASO methodology for implementation, explore further its challenges and opportunities, and support its implementation within the CREATIONS project.

4.2 Student needs addressed

Needs addressed are the creation of a Living Dialogic Space within creative science exploration, and rigorous engagement with Possibility Thinking (see CREATIONS Deliverable 2.1). Furthermore, there is a need to explore scientific material from the point of view of a variety of disciplines, such as drama, music, and visual arts. The CREATIONS project conceptualizes creativity at the meeting point of these domains, something which is exemplified in this demonstrator.

5. Learning Activities & Effective Learning Environments

WASO exercises a flexible implementation, which is adaptable to the specific school's time schedules, priorities, etc. WASO may be implemented with pupils as an intensive 2-week project in formal schools, as a short session over the course of a whole school year, or as an afternoon project in informal settings. The WASO school class simulates an "opera company" in which performers, composers, designers, scenographers, science educators, etc., collaborate to create an opera. There is therefore no "one size fits all" approach to the activity. Typically, though, a teacher will choose a scientific theme (in this case, star rotation), and engage the pupils in inquiry-based activities within both science and the arts.

For implementation in schools, the following may be required:

1. 2 classroom spaces (1 may be enough in some cases)
2. Musical instruments
3. Raw material for costumes
4. Stage (optional – WASO may be performed without an official stage)
5. Audio equipment for performance (optional – WASO can be performed "unplugged")
6. Access to scientific information (teacher/internet/book/research center)

The table below provides an outline for a WASO 2-day training seminar, in which teachers will participate in the process which they will thereafter guide their pupils in. Each phase (of 7 phases) will, during this training, last for 1-2 hours. Please note that when you will be implementing this intervention with pupils, it is recommended to take longer stretches of time. Optimally, a class would allocate 2 whole weeks to the WASO project. Alternatively, a teacher could opt to develop the WASO intervention over longer (e.g. one school year) periods, but rather engage with it for 2 hours a week.

Science topic: Elementary particles in the world of art: http://artcms.web.cern.ch/artcms/ Class information Year Group: 8-10 Age range: 13-15 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate, e.g. pupils with language difficulties may contribute on an equal level to others by performing in the orchestra.	Materials and Resources *What do you need?* Various music instruments, materials for making costumes. Optional: Stage, lights Where will the learning take place? On site or off site? In several spaces? (e.g . science laboratory, drama space etc), or one? Following a virtual visit to CERN, learning can take place in school and\or at science education center or museum. It is a good approach to have several rooms available during the phase where pupils are split into groups (see WASO Guidelines (Ben-Horin, 2014)). *Health and Safety implications?* In the case of sewing costumes, it is important to ensure maximum safety by having a qualified teacher available at all times and corresponding instructions. *Technology?* Computer with internet (watching videos and searching for information). This is especially important during virtual visit to CERN if applicable. *Teacher support?* Team teaching with both arts and science and arts (music\dance\design\drama) expertise is recommended.
Prior pupil knowledge	

No prior knowledge regarding particles is required for pupils. The idea of the demonstrator is to introduce the topic through the creation of the opera. Mathematics skills (calculations) will be needed. If pupils do have prior knowledge about elementary particles, they will still be able to profit from engaging with the scenario, but they will probably think about it in a deeper way.

No prior knowledge regarding the arts is needed for pupils. The WASO method caters to all pupils, and includes exercises in e.g. music composition which allow novices to compose simple sections of the opera.

Optional: music lessons including composition exercises; basic drama exercises; dance; arts & crafts classes; experience with school stage performances is an advantage

Assessment	**Differentiation**	**Key Concepts and Terminology**
The CREATIONS project (www.creations-project.eu) proposes guidelines for the assessment of activities with pupils and teacher training. Please refer to the website in order to access the relevant documents.	*How can the activities be adapted to the needs of individual pupils?* Teachers who have undergone WASO training will explore a variety of tools which may be chosen according to the needs of various pupils and levels of difficulty. Examples (science): Level of depth of scientific explorations / amount of phenomena chosen as topics. Examples (arts): choice of tonality, level of rhythmical complexity of songs, etc.	**Science terminology:** Higgs Boson, Photons, Neutrinos, Mass, Light. **Arts terminology:** 1) Aria: Solo song by one character. The plot's "action" is stopped to allow this character to express a certain emotion and inner feelings. 2) Duet: Two singers, preferably each singing their own verse followed by a section in which they sing together. 3) Ensembles: Three or more singers 4) Choir: The choir can be used to "comment" during the other songs, or as simple choir pieces.

		5) Overture: Instrumental (no voices) opening piece which sets the mood of the opera. 6) Interlude: Music performed between acts or scenes. 7) Recitative: "Spoken Song" which tells a story, and which propels the plot further by revealing action (what has taken place, what will take place, a secret, etc.). 8) Tableau– A dramatic activity in which a group of pupils are asked to physically construct an opera scene through body placement, facial expressions, and props 9) Various musical instruments

Session Objectives:

During this scenario, students will:

Explore the art@CMS website, and learn about modern research concerning the relevant particles (Neutrinos, Photons, Higgs Boson); Take part in a virtual visit to CERN; Experience musical, visual design, drama techniques as tools for the opera.

Students will gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the Science Opera, accompanied by a continued exploration of the particles. The

libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.

Throughout the scenario, pupils will learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Generate and writes down words\ideas about Neutrinos, Photons, Higgs Boson, and shares with others in order to learn from their previous knowledge.	Activates previous knowledge in the fields of scientific exploration, and introduces particles by means of a virtual visit to CERN.	Begin cooperation with music/fine arts/drama/dance teacher(s) at your school in order to explore those subjects. Examples: experimenting with various musical instruments and drama techniques.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students compare their ideas to existing evidence. Take part in virtual visit to CERN.	Guide students to relevant evidence.	Comparing artistic ideas to other art-works, especially school art works created by pupils. Give preference to art projects inspired by scientific phenomena.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse evidence and make conclusions regarding their own initiative.	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin creating and rehearsing the opera within the various arts disciplines (libretto, costumes, music, etc.)
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of scientific explanations.	Guide students in their consideration of possibilities.	Continued production of original material (music, etc.), and opera rehearsals.
Phase 5: **CONNECT:** students connect	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and	Ensure scientific quality with	Continued rehearsals, costumes making.

explanations to scientific knowledge	ideas and reflect on the strength of their evidence and explanations in relation to the original question.	artistic ideas may cross-fertilize each other within the inquiry process.	regard to explanations	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications.	Supports the communication process and the opera performance logistics	Opera performance: It is advised to invite community (parents, other teachers, etc.), and to include a short introduction by the pupils prior to the performance.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the scientific and artistic conclusions	Discuss the implications of a global collaboration with students	Reflection on the process, and collection of documentation of data to the extent possible / sharing experiences via social media.

6. Additional Information

The WASO Guidelines (Ben-Horin, 2014) provide a detailed over view of drama, music and other exercises, techniques, and more. Those guidelines were developed as part if the European Commission's "Implementing Creatives Strategies into Science Teaching" (CREAT-IT, 2014). The following warm-ups are provided here as reference:

Warm-ups

Warm-ups provide physical motion (stretching, running, breathing exercises, etc.), musical exercises (rhythm\pulse exercises), vocal training, creative exploration, as well as positive social exchange and group dynamic.

Sessions should begin with a warm-up, regardless of the session's length.

In the list below, some basic exercises are provided. In addition, teachers of physical education, drama, music and dance in your school will usually be able to add their own repertory of exercises.

Stretching Exercises

Begin with very simple stretching for a variety of areas of the body:

1) Roll shoulders in circular motion 3 times in each direction (forwards and backwards).

2) Roll head in circular motion 3 times in each direction (left and right). NB: Slowly!

3) Facial grimaces to stretch all face muscles (20-30 seconds).

4) Massage face, neck and back of neck with fingers (20-30 seconds).

5) Stand in a circle with each pupil's left shoulder facing out of the circle so that all pupils are facing the same direction in the circle. Ask each pupil to give her\his neighbor a shoulder and back massage for one minute. Thereafter, switch directions and repeat the exercise.

6) Pupils put hands together and reach as high as possible, on tip-toe. Count to 10 as they stand there. Repeat with eyes closed.

Breathing Exercises

Begin with very simple breathing exercises:

1) Pupils inhale (nose) with mouth closed while teacher counts to 4. They exhale (mouth) while teacher counts to 4. *When this exercise has been completed, proceed to 6, then 8. For pupils age 12 or older, proceed to 10.*

2) Inhale (nose) and, following teacher's cue, exhale for as long as possible on the sound "ss". Repeat the same exercise with the sound "sh", and then "f".

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3) Create various rhythms which blend nasal inhalation and mouth exhalation. *Note: These should be very short (3-4 seconds at most).*

Name Games

This game allows new groups to become acquainted which each other, while simultaneously allowing each member to present him\herself, see each other, and enhance group communication.

Step 1: Invite a group-member to say his\her name. The whole group then repeats that name, after which the next member says his name, and so on.

Step 2: Invite a member to say his name accompanied by a short bodily movement. The whole group must then repeat that name together with that movement. Repeat for all members.

Step 3: Invite a member to say her name with her corresponding movement, followed by her saying someone else's name and making that person's movement. That person takes over, repeats their own, and "sends" the game to a further member, and so on.

A more advanced version, for the higher grade levels, includes movements only (without names), increasing the need for memory and concentration.

Counting Game

Simple mathematics during which pupils sit in groups of two, facing each other, and must count to 3 together. Pupils A starts with 1, B continues with 2, A says 3, B says 1 and so on….The pupils are challenges to keep a steady rhythmical pulse. When they are well-rehearsed in this task, introduce a clap instead of the number 2. When the pupils have become comfortable with this stage, introduce a whistle instead of the number 3. Whistling while you laugh may not be so easy…

Movement Exercise (1) - "Friends!"

Step 1: Ask your pupils to move around freely in the room.

Step 2: While they are walking, ask each one to choose a "friend" in the room (but make sure they do not tell anyone who their "friend" is).

Step 3: While they are still walking, ask each one to choose an "enemy" in the room (but make sure they do not tell anyone who their "enemy" is).

Step 4: Ask your pupils to now make sure that their "friend" is between them and their "enemy", so as to "protect" them (make sure they understand that this should happen while they are still moving). It may take pupils 10-15 seconds to understand how the exercise works, but when they do, the result may be quite comical! Allow them to enjoy this for 30-40 seconds before starting another round. Repeat 2-3 times.

Movement Exercise (2) - "Lobsters!"

In this exercise, two of the pupils are assigned to be "lobsters", while all others are "humans". The "lobsters", walking on all fours (facing up), must touch one of the "humans", who then becomes a "lobster". The "lobsters'" goal is to turn everyone in the room into "lobsters". The last "human" in the room is the winner. *Note: Make sure there is ample space for movement, and that there are no loose objects which may fall off tables or shelves during this game (computers, expensive phones, etc.), as this game may be quite active!*

Movement Exercise (3) – "Hand on Red!"

In this exercise, call out a body part, and then a color on which pupils must place that body part. For example: Call out "Hand on Red!" after which pupils must place their hand on anything red in the room. The last pupil to have placed their hand on something red must call out the next round. Examples: "Foot on Green!", "Ear on White!", and so on. This game can go on for 3-4 minutes. *Teacher's Tips: Make sure there is nothing dangerous in the room, especially when working with very young children (glass bottles, etc.).*

7. Assessment

During your training workshop for teachers, you will be asked to assess the workshop. Please refer to the CREATIONS project website in order to learn more about assessment structures for pupils.

In assessing the WASO workshop / activities, it is important to consider the scientific content, the artistic content, as well as the creative environment of the activity as it emerges at the meeting point of science and art, with regard to the CREATIONS pedagogical principles (see CREATIONS D2.1).

8. Possible Extension

WASO may be implemented during a complete school year, and in more than one class in a school.

9. References

Chappell et al (2016). D2.1 CREATIONS Features of Inquiry. CREATIONS - Developing an Engaging Science Classroom, H2929-SEAC-2014-1 CSA, 665917.

Ben-Horin, O. (2014). D3.1 The WASO Guidelines: CREAT-IT project. Available at: http://www.opendiscoveryspace.eu/edu-object/write-science-opera-waso-guidelines-820499

CREAT-IT (2015). Project website. www.creatit-project.eu

D3.2.45 ART@CREATIONS

Project Reference:	H2020-SEAC-2014-1, 665917	**Authors:**	Oded Ben-Horin (HVL)
Code:	D 3.2.45.	**Contributors:**	Franz Bogner (Univ. of Bayreuth), Julia Wank (Univ. of Bayreuth), Sofoklis Sotiriou (EA), Petros Stergiopoulos (EA)
Version & Date:	**V1, 31/3/2017**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Music, computer animation and science.

1.2 Type of Activity

The demonstrator is exemplified by professional artists as examples of **school/research centre collaboration.**

1.3 Duration

Suitable for short demonstration activities (1-2 days) or longer activities.

1.4 Setting (formal / informal learning)

Suitable for both formal (e.g. school music lessons) and informal (e.g. after-school music, arts or science club).

1.5 Effective Learning Environment

- Arts-based
- Communication of scientific ideas to audience
- Dialogic Space / argumentation

2. Rational of the Activity / Educational Approach

2.1 Challenge

This demonstrator addresses a general challenge with regard to the learning of complex scientific topics (exemplified by the Big Bang, DNA structure, and the Neutrino Particle). The demonstrator *addresses the challenge of engagement with the scientific material on the arts' premises*. The question of the artistic quality and approach within an inter-disciplinary science/art environment deserves attention due to the unique qualities that the arts represent. Feelings. Emotions. Aesthetics. Relations with the audience in ways that surpass words and verbal explanations. But also how interaction and collaborative creation develops and *feels* in an arts-based project, in the arts' own domain. This demonstrator represents that perspective on (and within) the CREATIONS project.

2.2 Added Value

ART@CREATIONS enables the following pedagogical added value: The discussion of (and aiming) for artistic quality in the CREATIONS context provides an inherent place in the science lesson for emotions and feelings in ways which surpass verbal explanations. Within the framework of inquiry-based science teaching (presented in 3 scientific fields below), ART@CREATIONS places the arts education process on a similar level of focus to that of the science. It poses the following questions: What *kind* of science inquiry can be enabled through a discussion of the *artistic quality* within an arts-infused model of inquiry, which cannot otherwise be enabled? What kind of potential does this have for the *level of engagement* in the science classroom?

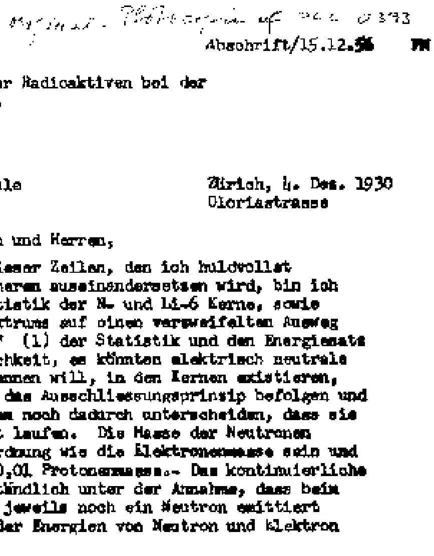
ART@CREATIONS will produce art, knowledge and experience regarding artistic inquiry within a science education framework: During 2017-18, Norwegian artists, inspired by (and in collaboration with) scientists and artists in the CREATIONS project, are producing several artworks and documenting the creative process of their CREATIONS. These will include both new and existing musical compositions set to scientific or science-inspired texts accompanied by newly-created animation movies. The artworks will be developed in dialogue with scientific organizations and inspired by scientific topics such as the Big Bang, particle physics research at CERN, and DNA. In 2018, these artworks will be used as inspiration for CREATIONS demonstrator workshops in schools.

The following are three inspirational examples from the fields of particle physics, astronomy and biology:

2.2.1 2.2.1 Particle Physics – "Liebe Radioaktive Damen und Herren"

«Liebe Radioaktive Damen und Herren" were the opening words of the letter in which Wolfgang Pauli shared the news of his new understanding of the (now-called) Neutrino particle with the science world. This music composition's text is based on the original letter[14] written by Pauli in which he announced the new particle's concept. The composition is recorded in the original (German) language of the letter.

[14]http://www.neutrino.uni-hamburg.de/sites/site_neutrino/content/e45939/e48540/e48541/e48544/infoboxContent48545/material-vorlesung1-moessbauer-pauli.pdf



Abschrift/15.12.56

Offener Brief an die Gruppe der Radioaktiven bei der Gauvereins-Tagung zu Tübingen.

Abschrift

Physikalisches Institut
der Eidg. Technischen Hochschule
Zürich

Zürich, 4. Dez. 1930
Gloriastrasse

Liebe Radioaktive Damen und Herren,

Wie der Ueberbringer dieser Zeilen, den ich huldvollst anzuhören bitte, Ihnen des näheren auseinandersetzen wird, bin ich angesichts der "falschen" Statistik der N- und Li-6 Kerne, sowie des kontinuierlichen beta-Spektrums auf einen verzweifelten Ausweg verfallen um den "Wechselsatz" (1) der Statistik und den Energiesatz zu retten. Nämlich die Möglichkeit, es könnten elektrisch neutrale Teilchen, die ich Neutronen nennen will, in den Kernen existieren, welche den Spin 1/2 haben und das Ausschliessungsprinzip befolgen und sich von Lichtquanten ausserdem noch dadurch unterscheiden, dass sie nicht mit Lichtgeschwindigkeit laufen. Die Masse der Neutronen müsste von derselben Grossenordnung wie die Elektronenmasse sein und jedenfalls nicht grösser als 0,01 Protonenmasse.- Das kontinuierliche beta- Spektrum wäre dann verständlich unter der Annahme, dass beim beta-Zerfall mit dem Elektron jeweils noch ein Neutron emittiert wird, derart, dass die Summe der Energien von Neutron und Elektron konstant ist.

Excerpt from the original letter by W. Pauli

The artistic concept was to integrate and embed elements of what has come to be known regarding the Neutrino particle in the artistic creation. Its mysteriousness is represented in an ever-changing harmonic scheme which defies prediction and is characterized by ambiguity. The unexpectedness of the way in which it was discovered and revealed is reflected in a perpetual rubato rhythmical approach.

Participating artists[15]:

- Music composition: Petros Stergiopoulos (concept, harmony and preliminary recordings, EA, Greece) and Oded Ben-Horin (melody and recitative, Western Norway University College, Norway).
- Video animation: Jose Eduardo Garcia Aldama (Volda University College, Norway).
- Performing musicians: Bettina Smith (mezzosoprano, University of Stavanger, Norway), Petros Stergiopoulos (MIDI synthesizer and flute) and Stein Inge Brækhus (percussion, University of Stavanger, Norway).
- Recording, mixing and mastering by Stein Inge Brækhus.
- Producer: Oded Ben-Horin

Link to the resource (sound file) in the CREATIONS project portal:
http://portal.opendiscoveryspace.eu/en/node/848712

2.2.2 2.2.2 Astronomy: The Big Bang

This inspirational example is based on the MITAKA[16] astronomy software which was created by the Japanese National Observatory in Tokyo. Through the creation of a MITAKA-based film which shows a journey through

[15] Participation of artists who are not part of the CREATIONS consortium was funded by UH nettVest (www.uhnettvest.no).
[16] http://4d2u.nao.ac.jp/html/program/mitaka/index_E.html

the universe towards the solar system, an artistic representation of astronomical questions will be explored by musicians, dancers and video artists.

The artwork is available here: https://www.youtube.com/watch?v=ABoT4YhM-FQ&feature=youtu.be

2.2.3 2.2.3 DNA

The 3rd inspirational example relates to the DNA. The artwork will explore a scientific text: the letter[17] from the scientist Francis Crick to his 12-year-old son Michael in 1953, weeks before the public learned about one of the most important scientific developments of modern times: Crick's co-discovery of the "beautiful" structure of DNA, the molecule responsible for carrying the genetic instructions of living organisms; or, as Crick explained it to 12-year-old Michael, "the basic copying mechanism by which life comes from life."

The artwork will include a class of school-children performing a "DNA Dance" inspired by the Biology team at the Univ. of Bayreuth.

[17] http://www.lettersofnote.com/2015/07/a-most-important-discovery.html

3. Learning Objectives

3.1 Domain specific objectives

The aim of ART@CREATIONS workshops in schools is to provide high school pupils with the opportunity to explore scientific themes relevant to their curriculum while reflection on the *artistic quality* of arts-based productions inspired by those scientific themes. Furthermore, those pupils will reflect upon the relationship between artistic quality (of both process and product) and science learning.

In practice, pupils may create musical compositions (with or without texts) and set these to originally-created (self-made by pupils) video animations. *Note: Pupils may choose to use live actors for their movies instead of animations.*

All ART@CREATIONS activities are recommended as collaborations with local science centers and/or laboratories. In addition, it is important to relate the activities to the science curriculum of the groups taking part. Thus, in the examples provided in section 2 (above), domain-specific objectives must be a focal point. In particle physics the area of exploration is the neutrino particle's characteristics and specifically its 3 flavors. In astronomy the area of exploration is the Big Bang and the creations of the solar system. In DNA/biology the area of exploration is the DNA structure.

- ART@CREATIONS teaches students how to engage with the question of artistic quality within an inter-disciplinary science and art learning environment.
- ART@CREATIONS teaches students how to negotiate the complex science-art domain while experiencing the role of the arts not only as a supporting element, but rather as a goal in its own right.

3.2 General skills objectives

- Active participation in discussions/exploration of science curriculum themes
- Music composition
- Creation of video animation (or other kinds of video)
- Interconnection of science and art disciplines
- Collaboration and dialogue skills
- Communication to relevant stake-holders beyond the classroom by sharing results via social media (Facebook, the CREATIONS project portal, school website, etc.).

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim is to engage high school students in creative science and art learning, from an arts perspective. ART@CREATIONS thus wishes to support pupils' cognitive involvement, their representation of scientific themes, emotional involvement, and social interaction and communication. The demonstrator will also provide specific skills (see below) in multi-disciplinary music/video creation.

4.2 Student needs addressed

The scientific theme for the high-school workshop should be chosen by pupils, thus providing them with ownership over the creative process (pupils may use the provided examples (DNA, Big Bang or Particle Physics) as starting points if needed). Freedom of selection supports immersion in active investigations of scientific issues, and engagement in collaborative discourse and creation. Students thus build on each other's ideas, enhancing learning of scientific concepts.

More specifically, a focus on the question of artistic quality within the science education framework will provide pupils with new creative approaches to the curriculum.

5. Learning Activities & Effective Learning Environments

Science topic: May be any scientific topic related to curriculum (e.g. Physics, Biology, Chemistry) (Relevance to national curriculum) Norwegian High School (Videregående) curriculuml Age range: 16-18 Sex: both Pupil Ability: Mixed (There is ample space for pupils of various abilities to participate)	Materials and Resources *What do you need?* Laptop with animation software (this may be any software available to pupils), basic video editing tools (in the case of "real-life" video", musical instruments, basic music recording software and hardware (e.g. Audacity, Cubase). *Where will the learning take place?* Activities will take place primarily in main classroom of pupils, in the school's music room, and in the technology lab/computer room. *Health and Safety implications?* *None* *Technology?* As specified above, as well as internet access. *Teacher support?* Music teacher with specialization in pupil composition techniques (this can be of any musical style and with or without lyrics), video teacher with animation expertise, and science teacher.
Prior pupil knowledge No prior pupils knowledge is required, yet the inclusion of music and/or media/video majors is an advantage.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will implement and reflect on four main areas: 1. The scientific theme of the scenario implemented. 2. Basic (or, for music majors, advanced) music composition, recording, playing techniques 3. Basic (or, for media/animation majors, advanced) video creation 4. Discussion/reflection of artistic quality based on the provided examples and the adaptation of these principles in the creation process		
Assessment Assessment (detailed below in section 7) is based on the CREATIONS project assessment for pupils (pre and post) and teachers, as well as a qualitative reflection on the role and potentials of exploring the quality of the artistic process in a science education context.	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Activities are open for all pupils. Within the Norwegian High School system (videregående skole) there are various programs (majors) with which more in-depth work may be implemented in the case of various disciplines. Examples may be music majors, science majors or media majors. It is recommended to take advantage of these opportunities, especially in the case of music and video/media, in the ART@CREATIONS Demonstrator, as it is perceived that those groups already have some background not only with the	**Key Concepts and Terminology** **Science terminology:** The scientific terminology is determined by each implementing class group. **Arts terminology:** Musical composition, video animation, artistic process versus product, artistic quality.

	"handwork" of art creation, but also the quest for artistic quality within those processes.	

Session Objectives:

During this scenario, students will **deepen their understanding on scientific concepts and phenomena, using their creativity and imagination**

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	*Ethics and trusteeship* is an important consideration in the initial choice of question.	Generate questions about the chosen topic.	Chooses scientific topic from school curriculum. Supports students' finding new questions about topic.	

Phase 2: **EVIDENCE:** students give priority to evidence	*Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Search books/internet for information relevant to topic. Work may occur in teams or individually.	Ensures that all students have access to information about the topic.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse scientific data.	Facilitates students' scientific process.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	*Playing* with ideas.	Students evaluate findings in light of alternative explanations.	Facilitates students' artistic process.	

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* and *interdisciplinary* knowledge to understand the origin of their ideas.	Students are divided into "specialty" groups according to the needs of the artwork they are creating (e.g. science, animation, composition, orchestra, studio recording groups).	Divides the students into groups and ensures constant flow of information between groups.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students.	Students communicate their inquiry findings by a public presentation of their work.	Arranges the public presentation and ensures it includes these elements: Introduction, short lecture about the scientific	

			exploration, the artworks, discussion about how students perceived artistic quality within the project.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Inter-disciplinarity*	All attendees of the event take part in a reflective discussion about how the students achieved in representing scientific topic by artistic means, and how they have interpreted "artistic quality" within the project.	Facilitates the reflective discussion or appoints a local artist and scientist to do so.	

6. Additional Information

Open Discovery Space (ODS) is an online platform where European teachers and students may share educational resources with others, including in other countries. ART@CREATIONS has a dedicated sub-community[18] within the main CREATIONS portal. Artworks will be uploaded and made available during the course of 2017-2018.

The ART@CREATIONS DNA DANCE example is being implemented at a primary school in Norway with an expected performance in May, 2018, at the Bergen Aquarium.

[18] http://portal.opendiscoveryspace.eu/community/artcreations-847564

7. Assessment

For quantitative assessment we use 'Science Motivation Questionnaire II (SMQ-II)' 19 (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) for pupils with both pre- and post questionnaires, and 'VALNET' questionnaires for teachers.

For qualitative assessment, a reflective discussion will be initialized (see phase 6, above) during which both scientific and artistic quality will be discussed. The main scope of this discussion will rely on learning about students' understandings of, and new ideas, regarding what represents a quality interaction between science and art within an educational environment. To this end, focus group discussions will be arranged with participating pupils. During the focus groups, semi-structures interviews will be conducted, and thereafter transcribed and analyzed.

[19] 2011 Shawn M. Glynn, University of Georgia, USA **http://www.coe.uga.edu/smq/**

8. Possible Extension: The artists' perspectives

The ART@CREATIONS takes the perspectives of the artist. To this end, the following are transcriptions of the ART@CREATIONS artists' views on quality in art and what the term "quality" may mean in the context of an arts-infused Inquiry-Based Science Education project which aims for Responsible Research and Innovation (RRI) as CREATIONS does. The interviews were conducted by the CREATIONS project representative ("C") and the artists ("A").

4.3 Animation artist

C: How long have u been working with animation for?

A: Since 2001

C: Could you provide some examples of previous projects?

A: I started in a big company, where usually each one does a part of the work. So my (first) job was just to colour images that someone else created on a computer. Then the company needed someone for a long feature film. And by the end of that year I was also doing music-related things, working with lights, shadows and effects. I kept doing that for some years, and then started progressing and got to be in charge of projects. Then, at University (audio-visual specialization) and working (simultaneously) at the company, we worked on many different kinds of projects (musical clips, commercials, etc.).

C: What do you aspire for as an artist?

A: When I was working in a big company, I used to work for many different people. One of the goals was trying to do as good as possible according to what the client wanted. Even when sometimes the client wouldn't know so much about animation, I tried to hold a balance between the commercial and the artistic.

C: What is artistic quality from your perspective?

A: Trying to do the job as well as possible: trying to not just please the client, but to also see the quality.

C: Yes, but what is the definition of that quality?

A: It is a bit dependent on what you like on a personal level.

C: So what do you *like?*

A: After many years of working in the industry, it is difficult to name just one thing. Earlier I wanted to make movies, but after a while what I liked was working in a group. The group had quality.

C: Why?

A: The script or the idea of the project, plus the way we made it…the details, the challenge for new things, when I go out of my comfort zone.

C: So two things need to be there for you to consider it of good quality: a good script or idea, and also a challenge of new things on a technical level (of actually doing it).

A: Yeah. Because usually it is a team-work, which can be difficult because you have to get together with what everybody wants…how to combine everyone's ideas to get the best…

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C: But how do you define what is a script of good quality?

A: It depends on what you want to tell, and how you want to tell it. You can have a pretty normal script but turn it into something really artistic…

C: How?

A: Through the way that you want to tell the story

C: Can you give me an example?

A: Okay…one of the last movies I made recently was with the team at the company and it was based on the prologue of a book by a Cuban writer…it was a small story, and we turned it into something really visual, and not in a conventional way of telling through animation stories

C: What do you mean by that?

A: First of all, it doesn't look like an animation film or movie…it was really poetic in a way, very visual, but telling the story through all these beautiful images and pictures.

C: Now, what is different in the artistic approach or quality in an art-science project such as this one?

A: Well, first of all, I am not a science person, and one of the things that I do when I start to read about a project is to visualize…everything comes to me through images…and in this project, one of the things I was concerned about was that it was very scientific and needs to be accurate, and I was afraid to go beyond that and make it too artistic, or going through another direction than the one that was requested.

C: But this was a very free and open project?

P: Yeah, but I was thinking that you'd want something as real as possible according to science, and I (at the) start wasn't sure, and my version of the neutrino particle…I don't know if someone who really knows about that would say….

C: But do you think that what you have been doing here is artistically satisfactory?

A: Yeah, but I (still) don't know what the reaction of the scientific community would be…

C: Why is it artistically satisfying?

A: Well, first of all I have been working with freedom, and everything came from my mind, I could translate through my software, and trying new techniques. And I think I produced something with good visual quality.

C: Yes, but how do you define that?

A: When I think about art, I think about emotions, feelings, about what the audience personally connects with. I think something can be perfect but you (audience) doesn't connect with it emotionally.

C: So how do you know it is of quality before you see the reaction of the audience?

A: I think you first have to be satisfied with what you have done, personally, as well.

C: So what makes you satisfied with this work?

A: OK….so for now it is this satisfaction of discovering new ways to work, going out of my comfort zone, and…

C: OK, so maybe it is not possible to totally describe it?

A: Yeah, you *feel* like it's right, or that you are proud of it, yeah?

C: So does the fact that this artwork was inspired by a scientific phenomenon change anything with respect to that?

A: No, I don't think so.

C: So is the difference, then, in the way you came about the idea?

A: Yes, because, first of all, it is a different purpose (for the artwork), it is a challenge that it is coming from the scientific…

C: Does the fact that it is coming from the scientific field push you out of your comfort zone in any way?

A: Yeah.

C: How?

A: OK…I don't know too much about this subject (of the Neutrino)…I didn't know what a Neutrino was before.,.in a certain way, even though it is really scientific, it is also open and abstract, so I can come in with different animations, and visual elements…than with previous projects.

A: Do you think the Neutrino is a good choice for a theme to work artistically because it has abstract elements (from our point of view)?

P: I think you could choose whatever theme you want, it's just in the way that you tell it, how you make the script, how you show it, how you develop the idea…because you could take the Neutrino phenomenon and give it to 3-4 different artists and then you'd get very different versions of an artwork…some more "artistic", some more precise, etc.

C: Thank you.

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- Craft, A. (2011). Creativity and Education Futures. Changing Childhood and Youth in a Digital Age.
- Maximiliane F. Schumm & Franz X. Bogner (2016) Measuring adolescent science motivation, *International Journal of Science Education, 38:3*, 434-449, DOI: 10.1080/09500693.2016.1147659

D3.2.46 HVL- ARTig Demonsrator

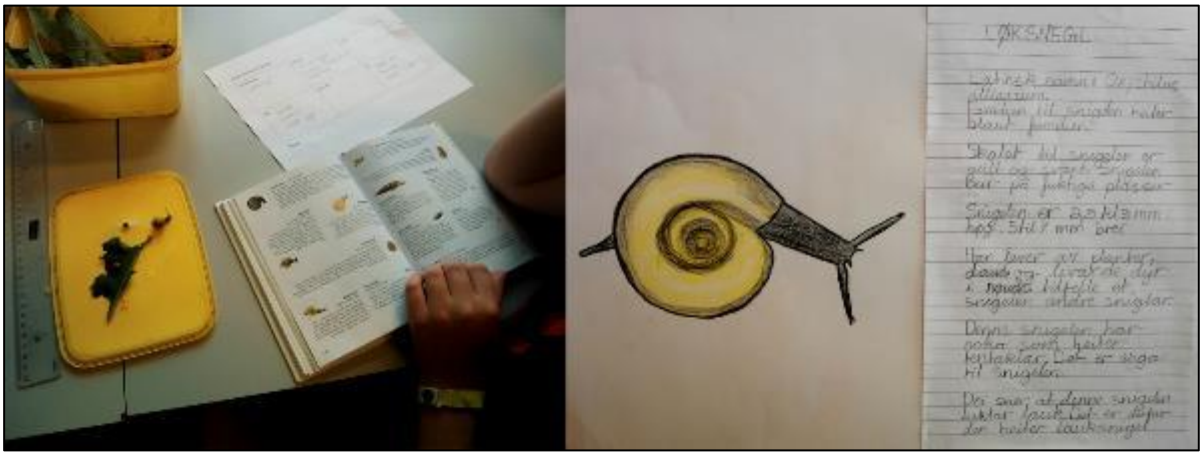
Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Charlotte Tvedte, Kari G. Nappen, Hannah B. Hansen (HVL)
Code:	D 3.2.46.	**Contributors:**	T. Hetland, O. Ben-Horin (HVL)
Version & Date:	V1 / 6.10.17	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

ARTig was developed at Stord/Haugesund University College in 2013 by the following researchers; Torunn Hetland (Norwegian) and Charlotte Tvedte (Arts and Crafts). At a later stage two additionals researchers were recruited in order to further develop the framework; Hannah Belsvik Hansen (Norwegian) og Kari Grutle Nappen (Science). The design is based on previous iterations implemented in Norway (Hetland and Tvedte, 2014).

1.2 Subject Domain

In this demonstrator, the specific scientific subject domain is biology/ the study of species.



6th graders experience with the ARTig-framework.

1.3 Type of Activity

Educational Activities based on Creativity-enriched Inquiry Based Approaches (school based).

Local level.

ARTig is a **local** educational activity based on **creativity-enriched inquiry-based** approach which is implemented in schools. As an example, the main focus of the implementation described here took place in a Norwegian primary school.

1.4 Duration

The teaching framework had the duration of three weeks. (Other ARTig-implementaions have lasted between one and eight weeks).

1.5 Setting (formal / informal learning)

Formal learning on the premises of the school.

1.6 Effective Learning Environment

This demonstrator relates to these characteristics within the learning environment;

- **Arts-based;** the pupils become conscious of others` ways of expression both with regard to illustration and textual descriptions of species.
- **Dialogic space / argumentation:** dialogue is a generic characteristic of the whole project. The dialogue between pupil and teacher. The dialogue between pupil and pupil which includes a constant argumentation for the choices they have made. The dialogue which emerges between the pupil and her own texts, artistic production and a variety of materials which allow for representation of different species` physical and other characteristics. (for example plaster, paper, string, recyclable materials)
- **Experimentation;** The project is based on the pupils` own inquiries of the various species. In this demonstrator we argue that the motivation for learning is to be found in the pupils` ownership with regard to their own findings.
- **Communication of scientific ideas to audience** in form of two exhibitions

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2. Rational of the Activity / Educational Approach

2.1 Challenge

ARTig fills a gap with regard to schools` capacity to introduce inquiry-based science education approaches and specifically those related to a focus on creativity. The overall challenge and inspiration for the meeting of the several disciplines is an interest for how one may nurture childrens` wonder and play in their interaction with nature at the same time as they learn to read and write scientific texts.

ARTig furthermore aims to support a respect for diversity of species in nature and understanding of the importance of sustainable development. This challenge relates to the issue of connecting the local to the global.

2.2 Added Value

ARTig relies on a concept which we refer to as "FRÅ FAKTA TIL FANTASI" (*from fact to fantasy*). Our framework relies on taking seriously childrens` sensual, creative and expressive sides in the meeting with both facts and science. We give pupils and their educators (in-service and pre-service) ownership of their *own knowledge and learning processes*.

In the creative process the focus is on expression which is specifically based on inputs which the pupil has previously received ("input to output"). At the same time, ARTig takes into consideration the development of pupils` social competences.

3. Learning Objectives

3.1 Domain specific objectives

- Knowledge of species and the development of new species (evolution)
- Writing scientific texts
- Reading scientific texts
- Arts and Crafts knowledge (drawing and the creation of sculptures) within the context of science education
- Science communication
- Gaining experience with the use of the local environment in science education

3.2General skills objectives

- Argumentation and negotiation of scientific knowledge/ Develop creative and critical skills
- A conscious determination to strengthen childrens` curiosity with regard to both science and arts learning.
- Understanding of scientific concepts and phenomena.
- Scientific interconnection of science with aspects of art (pupils will create a multi-disciplinary artistic exhibition - which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

ARTig is a multi-disciplinary teaching framework in which the following subject domains meet; science, Norwegian and Arts and Crafts. In this demonstrator, the specific scientific subject domain is biology/ the study of species.

This is an example of a scientific domain, but the authors would like to specify that ARTig may be adapted to further scientific domains in the future.

The teaching framework takes as its main source the scientific theme of the study of species (in Norwegian *artslære*), but also relates to other central themes and goals for competences in both Norwegian and Arts and Crafts. Artig relies to a large extent on a multi-modal understanding of science learning literature in which written text and visual images meet and co-exist.

The ARTig acronym is based on the following;

ART – ARTslære (the study of species)

ART – estetiske læreprosessar og estiske uttrykk (aesthetic learning processes and expressions)

ARTig – leikande tilnærming til læring (an approach to learning which recognizes the importance of play)

The ARTig demonstrator aims to provide late primary, secondary and high-school classes with an approach for the implementation of the framework. This involves the interaction with "real" nature and textbooks in order to receive inspiration for art-works which later are presented in exhibition form.

Note: ARTig's successful implementation necessitates the presence of either a teacher who has competences and specializations in all the related subjects (Norwegian, science and art). Alternatively, experts from the various disciplines must be present at all stages of the implementation.

4.2 Student needs addressed

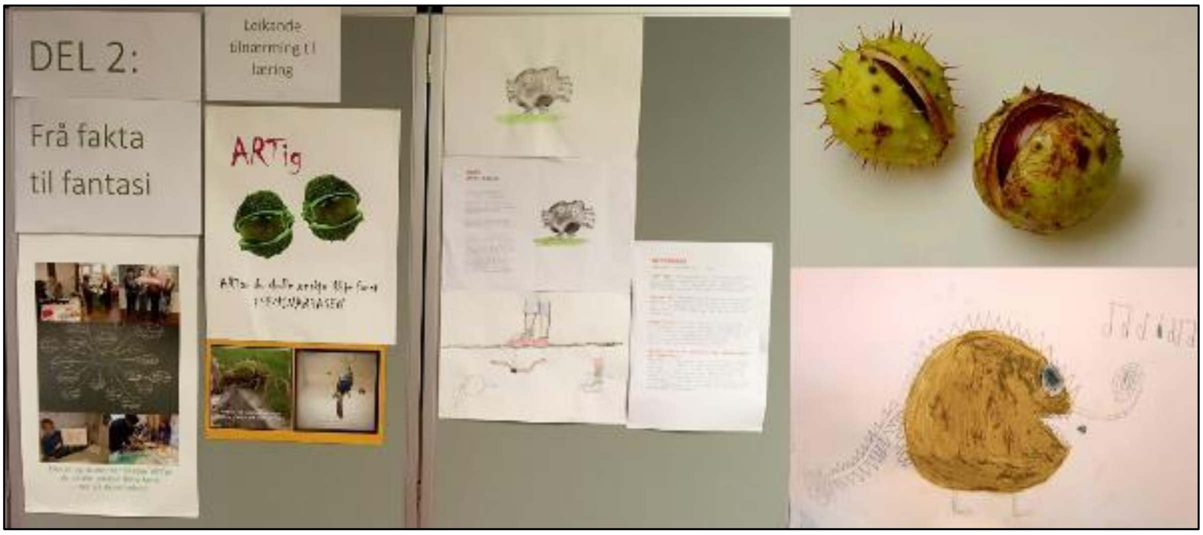
The need of pupils to experience "real nature" within their own local environment is specifically addressed by this ARTig demonstrator. Furthermore, ARTig is designed so that pupils create in pairs, responding to pupils' needs to learn to create knowledge within a collaborative and social context. Lastly, pupils' motivation is addressed in ARTig in several ways. As an example, the fact that the framework includes the communication of newly acquired knowledge to younger pupils than the partaking pupils themselves, provides this opportunity, thus increasing pupils' ownership of the learned material.

5. Learning Activities & Effective Learning Environments

ARTig is designed so that pupils will (in two parts) make the move from facts to fantasy. Through exploration, observation and descriptions, pupils get knowledge about the scientific theme. The first part relies on Erna Osland's book "*Under ein stein"* (2014) which is about scientific facts about species which literally can be found "under a rock", written as narrative essays, a form which resonates well with ARTig. In this part, the scientific exploration, observation-inspired drawing and writing following textual models, are the focus. The second part relies on pupils' development of their "own" species based on the scientific repertory which they have established in the first part. The meeting with the arts materials provides the impulse for this second, creation part. Here, they also take pictures of the pupils' new, "own" species, in the real natural habitat. Furthermore, they write a scientific text about their newly created species. In this way, pupils get the chance to use various materials to form their ideas and "new" species in a three-dimensional context.

Part 1:

Part 2:



The implementation requires the following:

- A room for the project
- An open space for the exhibitions

Science topic: Biology/species Relevance to national curriculum: The following themes are relevant as described in the Norwegian Education Ministry's "communication 28": An important didactic principle for ARTig is the multi-disciplinary collaboration for the various basic skills (reading, writing, verbal), creativity, and childrens' playful approach to school disciplines, deep learning and dialogue. Class information Year Group: late primary Age range: 9 – 12 yeras Sex: both Pupil Ability: ARTig is open to all pupils	Materials and Resources *What do you need?* Stereo Loupe, petri-dishes, terrarium, spoons, boxes/glass jars, paint-brushes, drawing and writing materials, aquarel pencils, computer, camera, scanner, scientific textbooks about species (e.g. insects, spiders, snails), string, newspapers, masking tape, plaster, recyclable materials, scissors, various textiles, transparent paper, tongs. For the exhibition, walls, tables, and a possibility to hang something from a ceiling is needed. *Where will the learning take place?* On-site and in local natural environment (e.g. in a park). *Health and Safety implications?* None. *Technology?* Internet, computer, scanner, digital camera. *Teacher support?* Teachers in Norwegian (or other language), science and Arts and Crafts.
Prior pupil knowledge There is no prior knowledge which is required from pupils.	

Individual session project objectives During this scenario, pupils will realize that there is a great diversity of species in their local environment. They will know several of the physical characteristics of these species, and how those characteristics impact those species' life-cycles. Pupils will furthermore learn to write in a scientific context and observation-based drawing (visual control) in an arts context. A main objective is to allow pupils to experience the meeting point of the various disciplines.		
Assessment The implementation described in this demonstrator occurred with 4th graders, and the evaluation therefore was based on Action Research interviews with teachers and pupils.	**Differentiation** Several of the pupils at the school are newcomers to Norway. For this reason, it was necessary to develop special mechanisms. For example, these pupils will be assigned, sub-goals which are specially adapted to their needs, especially with regard to the Norwegian language (writing and reading).	**Key Concepts and Terminology** **Science terminology:** Evolution, animal life-processes (nutrition, sensing, growth, reproduction), habitat and niche, and the species' place in the system of animal families. **Arts terminology:** Metaphor, comparisons between science and art, essay as genre in a scientific context, scientific illustrations, visual literacy and communication, terminology of multi-modal texts.
Learning activities in terms of CREATIONS Approach		

IBSE Activity	Interaction with CREATIONs Features	Pupil	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate.	Pupils are asked: Which species can you find "under a rock" (limited habitat) in your closest environment?	Teacher invites pupils to explore "real nature".	Painting in order to capture forms with the drawn line. Preliminary ideas for essays are developed.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils must observe themselves, and build up their observations based on evidence in scientific textbooks, internet, etc.	Teacher supports and continues to pose questions in both verbal and written (pre-written guiding questions) format.	Drawing and essay creations continue. Drawing takes place individually, while texts are written in pairs.

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils use the written guided questions in order to analyze their species and evidence.	Teacher helps pupils in order to identify facts, evidence and the relations to existing literature.	Drawing and essay creations continue while constantly questioning how these activities may impact analysis.
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils create a multi-modal text which explains their findings.	Teacher tries to identify issues related to the specific species which are surprising, and which can have a special meaning for us as humans, and points this out to the pupils.	Pupils create a multi-modal text which explains their findings and which can support dialogue activities in new ways.

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils continue to relate their newly-found knowledge with existing scientific literature.	Teachers support the connections between the various species and the existing knowledge in textbooks. Here it is crucial that the teacher uses various support strategies (drawing based on models, on photo images of the species, training through example, verbal feedback, etc.).	Pupils achieve a satisfying realization in that their visual creations are similar to the real species.

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	The scientific communication is contained in the texts and drawings which the pupils exhibit. In addition, pupils verbally present what they have discovered about the specimens.	Supports the exhibition creation.	The creation of an exhibition which includes multi-modal texts, terrariums, textbooks and the pupils' original drawings.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection is an inherent part of the complete ARTig process. The pupils will be lead into a process of realizing the connections between Norwegian language learning, Arts and Crafts and science.	Poses questions and deepens the reflection process by supporting an understanding of how the various elements of the process combine.	

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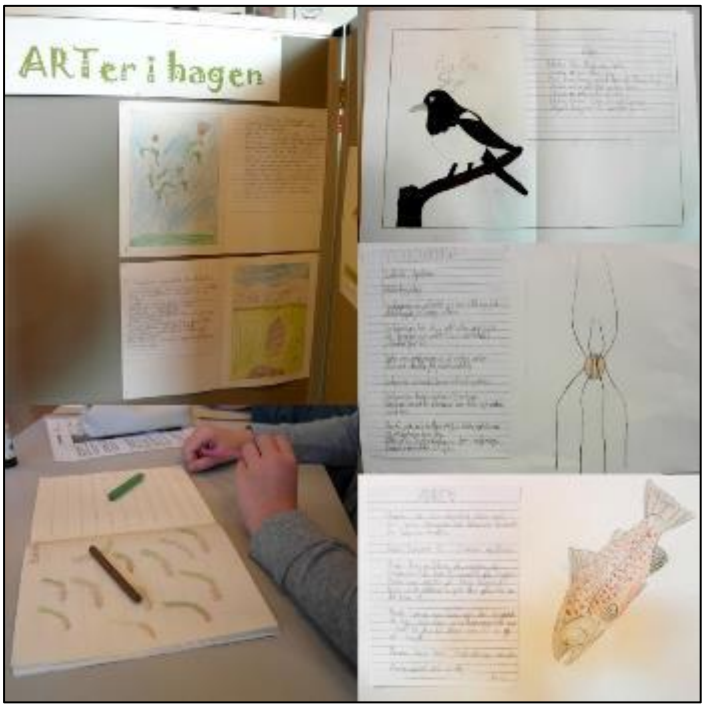
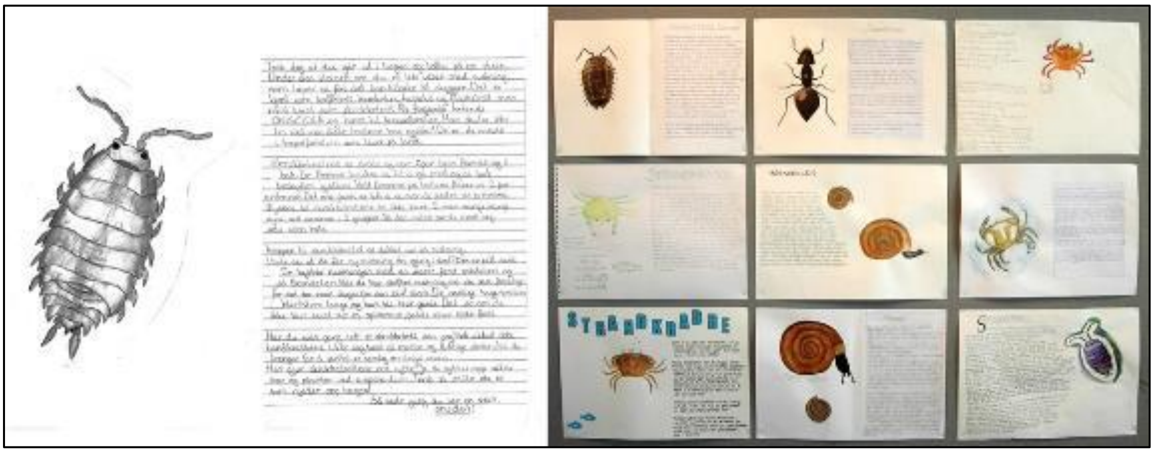
6. Additional Information

ARTig has been implemented with both primary school pupils, and in-training teachers at Stord Haugesund University College. The following two images exemplify both.



6th graders experience with the ARTig-framework.



Example of in-training teacher experience with ARTig framework

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

The implementation described in this demonstrator occurred with 4th graders, and the evaluation therefore was based on Action Research interviews with teachers and pupils.

We aim to cast light on the following themes and questions by interviewing pupils:

- Pupils tell about their own products and processes in the various phases of the ARTig activity.
- Pupils tell about their perceptions of being a "nature researcher"
- What during the activity motivated and engaged the pupils, and what did not?
- Have the pupils worked with scientific themes in the same way (during ARTig) as they have during previous science lessons?
- Has the ARTig activity contributed or changed the pupils' attitudes towards science? *(note: this is a relatively abstract question for pupils of this age, and may need to be adapted).*
- About seeing, studying, drawing and writing in and for learning science.
- About using books/texts other than science books/texts in science education.
- Whether the pupils wish to work with science and science education in the future.
- What are the pupils' thoughts about varied ways of teaching?
- What are the pupils' thoughts about practical, hands-on teaching?
- Writing in pairs and collaboration for creative expression in the ARTig activity

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8. Possible Extension

The ARTig team considers the framework to be applicable to a variety of scientific topics. The underlying issue here is observation of a phenomenon, and use arts-based knowledge and processes in order to deepen one's experience. This can therefore be extended to areas such as environmental concerns, plant life, life in earlier times (Stone-age), and more.

While we hold that to be true, it is crucial for the ARTig approach that the pupils' exploration begins in the local environment in order to establish a sense of wonder and appreciation for the nearest surroundings.

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Liv Merete Nielsen. Form nr 1 - 2001. s 8 - s 11

D.3.2.47 Atoms & Molecules at Rubbestadneset

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Oded Ben-Horin (HSH/HVL)
Code:	D 3.2.47.	**Contributors:**	
Version & Date:	3.0 / May 3rd, 2017	**Approved by:NKUA**	

The Demonstrator describes and plans CREATIONS implementation at Rubbestadneset School in the Bømlo Municipality in the South-Hordaland region of Norway. The implementation's theme will be "Atoms & Molecules", and corresponds to the Norwegian curriculum for the 8-9th grades. The methodology employed relies on some elements of the Learning Science Through Theater (LSTT) and Write a Science Opera (WASO) teaching approaches. Differing from those approaches, though, Atoms & Molecules does not culminate in a traditional performance, but rather a presentation of the process to the school.

Pupils will take part in a week-long intervention that will include workshops, presentation and evaluations.

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Subject domain for science is "Atoms & Molecules", based on the Norwegian curriculum for science for the relevant age groups. Specifically, the intervention relates to the Norwegian Competence Aims[20] following Grade 10, "Phenomena and substances». Furthermore, arts subjects include visual arts, music, drama, lighting and design.

1.2 Type of Activity

Type of activity is a creative teaching approach to inquiry-based science and art education in which pupils of different ages, supported by teachers, artists and scientists, take part in a creative process and are thereafter the creators of an educational presentation.

Rehearsals at Rubbestadneset School (Picture courtesy of www.bomlonytt.no)

1.3 Duration

This demonstrator describes a 1-week (5-day) workshop at Rubbestadneset School[21], whereby day 1 is dedicated to preparations and pre-evaluation of pupils, days 2-4 are dedicated to the creative process and presentation, and day 5 is dedicated to summary, post-evaluation and planning future collaboration where possible.

[20] https://www.udir.no/kl06/NAT1-03/Hele/Kompetansemaal/competence-aims-after-year-level-10?lplang=eng
[21] https://www.bomlo.kommune.no/tenester/skule-og-oppvekst/rubbestadneset-skule/

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1.4 Setting (formal / informal learning)

The intervention will take place in formal schooling. The head-teacher has allowed the 8th-9th grade classes to dedicate their time solely to the CREATIONS implementation during this week. On the last day of implementation, the resulting "Atoms and Molecules" process presentation will be displayed for the entire school.

1.5 Effective Learning Environment

This demonstrator relates to the following categorizations (see CREATIONS D2.3 for further detail):

- **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

An arts/science training will take place with several teachers from the school in order to prepare them for the scenario. The learning environment is collaborative, creative and flexible. It includes much movement (e.g. drama exercises), and approximately halfway through the project the class is divided into groups to create an "opera company" (orchestra, PR group, singers, light specialists, etc.): a non-typical classroom situation based on a "workshop" atmosphere, and in which unexpected questions and situations may arise, as pupils take charge of the learning process and the communication of that learning.

2. Rational of the Activity / Educational Approach

2.1 Challenge

The theme of atoms and molecules was chosen as it represents an area of science which pupils find challenging to engage with due to the abstract character in traditional learning environments. The very fact that pupils cannot "see" the material being discussed is challenging. Also, some pupils find the many different elements and the mathematical procedures needed in order to understand this area of science deeply, to be challenging.

2.2 Added Value

The approach provides learning opportunities in which pupils may cross-inspire and learn from and with each other in a creative school environment. To this end, CREATIONS offers the teachers an inspirational workshop before the implementation with pupils. Teachers will thus learn to engage pupils in science inquiry in new, creative ways. Pupils will, during implementation in schools following the training workshop, be able to explore scientific questions through drama, music and visual arts. In this way they will gain access to the scientific material which is being taught from a large variety of perspectives.

3. Learning Objectives

3.1 *Domain specific objectives*

The scientific theme of this demonstrator is to explore Atoms & Molecules, and specifically, elements Na, Cl, H, O, and interactions between them as molecules.

In the arts education domain, the objectives are to learn school opera as a methodology, including specific skills and inquiry with the various included arts education domains (music, drama, scenography, light design, etc.).

More specifically, pupils will:

- Finalize and perform a multi-disciplinary artistic presentation.

- Engage in activities which inspire curiosity around Atoms & Molecules; Explore musical, visual design, drama techniques as tools for the opera. *Note: Teachers may decide the science opera's specific topic within the larger theme (e.g. the water molecule) before the project or allow pupils to choose the scientific topic themselves. Each approach has its advantages: In the case in which the teacher chooses the specific topic prior to the project, it will be possible to realize the project during a shorter time-span. On the other hand, pupils may experience greater ownership and agency if they are allowed to choose the opera's theme themselves.*

- Gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the intervention, accompanied by a continued exploration of Atoms & Molecules. *The libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.*

3.2 *General skills objectives*

The objective of skills may be seen as developing social and emotional skills, cognitive skills, and, especially, meeting points between these, within an international context. Creativity and critical thinking, both considered to be "21st century skills", may largely be said to occur in the interaction, and cross-fertilization between these groups of skills (OECD, 2015).

Specific skills:

- Active participation in the negotiation of scientific concepts
- Developing creative and critical skills
- Understanding of scientific concepts and phenomena
- Familiarization with interconnection of science with aspects of art (supporting discipline knowledge in both the science and arts educational disciplines).
- Developing a spirit of cooperation and teamwork

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to describe, support and document the implementation of CREATIONS project at Rubbestadneset school. Specifically, in relation to the challenges described above, the demonstrator supported a long, in/depth exploration of a single molecule (NaCl) and its component elements, as well as its interactions with water, in order to allow the pupils to deeply understand and *experience* the scientific knowledge needed to understand this issue. Indeed, the uniqueness of this demonstrator lies in the fact that the scientific topic did not attempt to cover a large field, but rather focus on a single molecule's interaction, during the whole week. Through this, we attempted to exemplify to the pupils the *kind* of experience they will need in order to master other, perhaps more complex, chemical reactions.

CREATIONS at Rubbestadneset, Bømlo (Norway)

4.2 Student needs addressed

As stated above, students' needs in the case of the current scientific topic, relate to a tangible "connection" with the abstract concept of atoms and molecules. By granting the elements (e.g. Na, Cl) personifications, drama characters, and social and emotional characteristics through CREATIONS activities, we are allowing them to develop a connection with the learning theme, which goes well beyond the purely theoretical. By allowing pupils to incorporate their own artistic process into the science learning, and by allowing them to find their *own* contribution to the learning process, we grant them the possibility of becoming more familiar with crucial elements in the scientific study.

5. Learning Activities & Effective Learning Environments

The general approach is adaptable to the specific school's time schedules, priorities, etc. In the case of the current intervention, CREATIONS team and the school teachers met to discuss and plan the implementation and decided upon the 1-week plan mentioned above. The pupils (25 in total) will simulate an "opera company" in which performers, composers, designers, scenographers, science educators, etc., collaborate to create a performed artwork. There is no "one size fits all" approach to the activity and the CREATIONS trainers expect to see emerging content during the project implementation.

The following is required during implementation:

7. 2 classroom spaces
8. Musical instruments
9. Raw material for costumes and scneography
10. Stage
11. Audio equipment for presentation of process at the school.
12. Musical instruments

The table below provides an outline for a 1-week workshop. Each phase (of 7 phases) will, during this training, last for several hours.

Science topic: Atoms & Molecules Class information Year Group: 8-9 Age range: 13-14 Sex: both Pupil Ability: General public school. The scenario allows space for pupils of various abilities to participate, e.g. pupils with language difficulties may contribute on an equal level to others by performing in the orchestra.	Materials and Resources *What do you need?* Various music instruments, materials for making costumes. Optional: Stage, lights *Where will the learning take place?* Learning and corresponding presentation will take place at Rubbestadneset School. *Health and Safety implications?* In the case of sewing costumes, it is important to ensure maximum safety by having a qualified teacher available at all times and corresponding instructions. *Technology?* Computer with internet (watching videos and searching for information). *Teacher support?* Team teaching with both arts and science and arts (music\dance\design\drama) expertise is recommended.

Prior pupil knowledge
No prior knowledge is required for pupils, except successful completion of the standard Norwegian curriculum of the relevant age group. No prior knowledge regarding the arts is needed for pupils. The approach caters to all pupils, and includes exercises in e.g. music composition which allow novices to compose simple sections of the opera. The CREATIONS implementation team will, however, be flexible and interested to include any additional extra-curricular activities which pupils may be interested in. Pupils with special knowledge in e.g. piano playing, dance, etc., will be able to find space during the project to make use of these interests and talents.

Assessment	**Differentiation**	**Key Concepts and Terminology**

Assessment will be done in the form of online evaluation (pre- and post) completed by pupils online. Teachers will also complete evaluation forms online. All questionnaires have been translated into Norwegian.	*How can the activities be adapted to the needs of individual pupils?* The approach allows adaptation to various interests and needs of different pupils. This is true for both science and the arts. Examples (science): Pupils who require extra focus on a challenging point in the curriculum may be supported as the intervention exercises great flexibility regarding the design of its implementation. Examples (arts): choice of tonality, level of rhythmical complexity of songs, etc.	**Science terminology:** Atoms, Molecules, Elements, Periodic Table, Electrons, Protons **Arts terminology:** 1) Tableau– A dramatic activity in which a group of pupils are asked to physically construct an opera scene through body placement, facial expressions, and props 2) Various musical instruments 3) Scenography – the visual settings and design of the stage

Session Objectives:

During this scenario, students will: Explore a specific topic within the theme of Atoms & Molecules; Experience musical, visual design, drama techniques as tools for the presentation of the process. Students will gain knowledge and experience with group-work. The "opera libretto" will include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music. Throughout the scenario, pupils will learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Generate and writes down words\ideas about Atoms and Molecules, and shares with others. *Note: It is highly recommended to include a hands-on scientific experiment at this phase in order to elicit questions.*	Activates previous knowledge in the fields of scientific exploration, and introduces scientific knowledge about the topic, mainly in the form of inquiry-based questions.	Experiment with various musical instruments and drama techniques. This should be done in the form of question, such as "how can we communicate the structure of the water molecule through drama?
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students compare their ideas to existing evidence.	Guide students to relevant evidence.	Comparing artistic ideas to other art-works, especially school art works created by pupils. Give preference to art projects inspired by

				scientific phenomena.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse evidence and make conclusions regarding their own initiative.	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin creating and rehearsing the opera within the various arts disciplines (libretto, costumes, music, etc.)
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of scientific explanations for what they have discovered and learned.	Guide students in their consideration of possibilities.	Continued production of original material (music, etc.), and opera rehearsals.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and artistic ideas may cross-fertilize each other within the inquiry process.	Ensure scientific quality with regard to explanations	Continued rehearsals, costumes making.

	of their evidence and explanations in relation to the original question.			
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications. Example of communication through the Bømlo Municipality website: https://www.bomlo.kommune.no/tenester/skule-og-oppvekst/rubbestadneset-skule/eit-spennande-og-kreativt-prosjekt-i-naturfag-med-elevane-pa-8-og-9-trinn.226095.aspx	Supports the communication process and the presentation logistics	Process presentation: It is advised to invite community (parents, other teachers, etc.), and to include a short scientific introduction by the pupils prior to the presentation.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the scientific and artistic conclusions	Lead the reflection process and ask relevant questions which relate to *change.*	Reflection on the process, and collection of documentation of data to the extent possible / sharing experiences via social media.

6. Additional Information

The WASO Guidelines (Ben-Horin, 2014) provide a detailed over view of drama, music and other exercises, techniques, and more. Those guidelines were developed as part if the European Commission's "Implementing Creatives Strategies into Science Teaching" (CREAT-IT, 2014). The following warm-ups are provided here as reference:

Warm-ups

Warm-ups provide physical motion (stretching, running, breathing exercises, etc.), musical exercises (rhythm\pulse exercises), vocal training, creative exploration, as well as positive social exchange and group dynamic.

Sessions should begin with a warm-up, regardless of the session's length.

In the list below, some basic exercises are provided. In addition, teachers of physical education, drama, music and dance in your school will usually be able to add their own repertory of exercises.

Stretching Exercises

Begin with very simple stretching for a variety of areas of the body:

1) Roll shoulders in circular motion 3 times in each direction (forwards and backwards).

2) Roll head in circular motion 3 times in each direction (left and right). NB: Slowly!

3) Facial grimaces to stretch all face muscles (20-30 seconds).

4) Massage face, neck and back of neck with fingers (20-30 seconds).

5) Stand in a circle with each pupil's left shoulder facing out of the circle so that all pupils are facing the same direction in the circle. Ask each pupil to give her\his neighbor a shoulder and back massage for one minute. Thereafter, switch directions and repeat the exercise.

6) Pupils put hands together and reach as high as possible, on tip-toe. Count to 10 as they stand there. Repeat with eyes closed.

Breathing Exercises

Begin with very simple breathing exercises:

1) Pupils inhale (nose) with mouth closed while teacher counts to 4. They exhale (mouth) while teacher counts to 4. *When this exercise has been completed, proceed to 6, then 8. For pupils age 12 or older, proceed to 10.*

2) Inhale (nose) and, following teacher's cue, exhale for as long as possible on the sound "ss". Repeat the same exercise with the sound "sh", and then "f".

3) Create various rhythms which blend nasal inhalation and mouth exhalation. *Note: These should be very short (3-4 seconds at most).*

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Name Games

This game allows new groups to become acquainted which each other, while simultaneously allowing each member to present him\herself, see each other, and enhance group communication.

Step 1: Invite a group-member to say his\her name. The whole group then repeats that name, after which the next member says his name, and so on.

Step 2: Invite a member to say his name accompanied by a short bodily movement. The whole group must then repeat that name together with that movement. Repeat for all members.

Step 3: Invite a member to say her name with her corresponding movement, followed by her saying someone else's name and making that person's movement. That person takes over, repeats their own, and "sends" the game to a further member, and so on.

A more advanced version, for the higher grade levels, includes movements only (without names), increasing the need for memory and concentration.

Counting Game

Simple mathematics during which pupils sit in groups of two, facing each other, and must count to 3 together. Pupils A starts with 1, B continues with 2, A says 3, B says 1 and so on….The pupils are challenges to keep a steady rhythmical pulse. When they are well-rehearsed in this task, introduce a clap instead of the number 2. When the pupils have become comfortable with this stage, introduce a whistle instead of the number 3. Whistling while you laugh may not be so easy…

Movement Exercise (1) - "Friends!"

Step 1: Ask your pupils to move around freely in the room.

Step 2: While they are walking, ask each one to choose a "friend" in the room (but make sure they do not tell anyone who their "friend" is).

Step 3: While they are still walking, ask each one to choose an "enemy" in the room (but make sure they do not tell anyone who their "enemy" is).

Step 4: Ask your pupils to now make sure that their "friend" is between them and their "enemy", so as to "protect" them (make sure they understand that this should happen while they are still moving). It may take pupils 10-15 seconds to understand how the exercise works, but when they do, the result may be quite comical! Allow them to enjoy this for 30-40 seconds before starting another round. Repeat 2-3 times.

Movement Exercise (2) - "Lobsters!"

In this exercise, two of the pupils are assigned to be "lobsters", while all others are "humans". The "lobsters", walking on all fours (facing up), must touch one of the "humans", who then becomes a "lobster". The "lobsters'" goal is to turn everyone in the room into "lobsters". The last "human" in the room is the winner. *Note: Make sure there is ample space for movement, and that there are no loose objects which may fall off tables or shelves during this game (computers, expensive phones, etc.), as this game may be quite active!*

Movement Exercise (3) – "Hand on Red!"

In this exercise, call out a body part, and then a color on which pupils must place that body part. For example: Call out "Hand on Red!" after which pupils must place their hand on anything red in the room. The last pupil to have placed their hand on something red must call out the next round. Examples: "Foot on Green!", "Ear on White!", and so on. This game can go on for 3-4 minutes. *Teacher's Tips: Make sure there is nothing dangerous in the room, especially when working with very young children (glass bottles, etc.).*

7. Assessment

CREATIONS implementations are assessed by both pupils and teachers. Evaluation analytics will show the effectiveness and efficiency of employing creative teaching approaches. The web analysis will be used to show a change in the users-behaviour. The evaluation approach of the CREATIONS project will use both qualitative and quantitative approaches. The umbrella question is: ***can the implementation of the* CREATIONS *features influence science motivation, or motivation for pursuing science respectively?***

Further details:

- Teachers fill out a short questionnaire (VALNET) regarding the impact of CREATIONS activities on the curricula. This will support the connection of CREATIONS with different schools and policy makers. In Norwegian, the link to this questionnaire is:
- Pupils fill out questionnaire pre- and post intervention (Science Motivation Questionnaire (SMQ). For Norwegian the link is: https://docs.google.com/forms/d/1I5pUgFmFn-1oUqkhdauxnC4jAKv_6lIMOjgwO2YKAdM/viewform?ts=58174c17&edit_requested=true

8. Possible Extension

9. References

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.48 EQUIVALENT FRACTIONS!

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Maru A. Guadie (Western Norway University of Applied Sciences) - Mathematics
Code:	D 3.2.48.	**Contributors:**	Oded Ben-Horin (Western Norway University of Applied Sciences) - Drama
Version & Date:	2.0 / April 27th, 2018	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Fraction education in the Norwegian secondary school.

1.2 Type of Activity

Local educational activity based on Creativity-enriched Inquiry-Based Approaches (school based). Activities are structured as workshops.

1.3 Duration

1 working day.

1.4 Setting (formal / informal learning)

Formal learning on the premises of the school.

1.5 Effective Learning Environment

This demonstrator relates to the following categorizations (see CREATIONS D2.3 for further detail):

- **Arts-based** which addresses and enhances STEM interconnection with art education practices.
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of enquiry in STEM.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Many pupils face challenges comprehending fractions due to several factors. Firstly, there may be confusion as to why (and how) fractions may be represented in other ways, such as percentages. Secondly, in fractions, a number is represented by more than one digit. Thirdly, and specifically in the terms of the current CREATIONS demonstrator, equivalent fractions require several complex steps including e.g. calculations of common denominators.

2.2 Added Value

This Demonstrator provides learning opportunities in which pupils may cross-inspire and learn from and with each other in a creative school environment. Pupils are consequently able to explore mathematical questions through drama education exercises. In this way, they will gain access to the mathematical material which is being taught from a variety of perspectives.

Specifically, it offers the following added values: The designing of activities which explore the math curriculum deeply through an artistic form, and allowing that group to interact with the rest of the school (for example in the form of a performance), provides additional classes in the school with an understanding, intuition and respect for arts integration and its capacities in education.

3. Learning Objectives

3.1 Domain specific objectives

The demonstrator's domain-specific objectives are to:

- Focus on a specific mathematical topic (equivalent fractions).
- To learn drama as a methodology within inquiry-based questions in mathematics.
- Finalize and perform a short multi-disciplinary artistic performance (school drama) which demonstrates and deepens mathematic and emotional understanding of the learning processes, supporting discipline knowledge in both mathematics and arts.
- Engage in activities which inspire curiosity around equivalent fractions
- Explore drama techniques as tools.
- Gain knowledge and experience with group-work in which various groups will create specific elements related to drama and mathematics.

3.2 General skills objectives

Specific skills:

- ➢ Active participation in the negotiation of mathematic concepts with others
- ➢ Understanding of mathematic concepts and phenomena
- ➢ Understanding the potential of meeting points of math with drama
- ➢ Cooperation and teamwork

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to provide students with a methodology for implementation of a drama process inspired by mathematical concepts. It aims to lead to dramatic representations of the mathematical topic of equivalent fractions. Students are invited to, for example:

- create dramatic sequences in which the *relationships between characters* demonstrate the relationships between numbers in a fraction.
- Envision a dramatic sequence in which the *dramaturgical structure may resemble the fractions* themselves (e.g. a story "divided" in two).

This activity necessitates the presence of a group of teachers comprised from both visiting experts in mathematics and art (e.g. from the CREATIONS project) and several dedicated teachers from the school. The demonstrator aims for *emotional* involvement on the part of the pupils within a *social* learning environment. A holistic approach to learning is created through the constant necessity of pupils' making connections and understanding common themes across disciplinary boundaries.

4.2 Student needs addressed

The demonstrator allows students to engage with complex questions about equivalent fractions through a large variety of approaches (drama techniques, personified characters, etc.), thus allowing in-depth interaction with these questions over a long period of time, and in a variety of ways.

The demonstrator allows the students to experience *ownership* over the learned material, as it has empowered them to co-create the lesson together with their co-students and teachers by means of their contributions to the drama scenario.

For example, curiosity and ownership towards the equivalent fractions may be enabled through the invitation of students to represent specific numbers in the fractions, as characters in the dramatic sequence. They therefore "become" the fraction with the support of drama techniques as tools.

5. Learning Activities & Effective Learning Environments

The students take part in activities following guidance by instructors in both drama and mathematics. Typically, for implementation in schools, the following may be required:

13. 2 classroom spaces
14. Raw material for costumes
15. Stage (optional – may be performed without an official stage)
16. Audio equipment for performance
17. Access to mathematical information (teacher/internet/book/research center)

The following table outlines the learning activities and effective learning environments:

Science topic: Equivalent fractions Class information Year Group: 8-10 Age range: 13-16 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate, e.g. pupils with language difficulties may contribute on an equal level to others.	Materials and Resources *What do you need?* Materials for making costumes. Optional: Stage, lights *Where will the learning take place?* All activities will take place at the school. *Health and Safety implications?* None. *Technology?* Computer with internet (watching videos and searching for information). *Teacher support?* Team teaching with both mathematics and drama expertise is required.

Prior pupil knowledge

Basic knowledge in number system is required for pupils. The idea of the demonstrator is to introduce a mathematical topic: equivalent fractions. No prior knowledge regarding the arts is needed for pupils. The method caters to all pupils.

Assessment	**Differentiation**	**Key Concepts and Terminology**
The CREATIONS project (www.creations-project.eu) proposes guidelines for the assessment of pupils.	*How can the activities be adapted to the needs of individual pupils?* The implementation is structured to include the whole class. It is the creative process of	**Math terminology:** Fractions, equivalent fractions, proper and improper fractions.

These are realized before and after the school implementation.	generating ideas as a group and implementing them which is at focus, rather than a level of virtuosity in drama.	**Arts terminology:** Tableau – A dramatic activity in which a group of pupils are asked to physically construct an opera scene through body placement, facial expressions, and props. Climax – a point in the drama where the emotional state is most intensive Conflict and resolution – crucial points in the dramaturgical structure of the exercise

Session Objectives:

During this scenario, students will inquire about equivalent fractions; Experience drama techniques. Pupils will gain knowledge and experience with group-work in which various groups will create specific synopsis, script, and costumes (optionally) accompanied by a continued exploration of questions relating to equivalent fractions. The dramatic script should include key concepts connected to equivalent fractions (division, quotient, proportionality, ratio). Throughout the scenario, pupils will learn to make their **own decisions** during inquiry processes, and make their **own connections** between questions.

Learning activities in terms of CREATIONS Approach

Inquiry-Based Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a mathematically oriented question	Students pose, select, or are given a mathematically oriented question to investigate. Questions may arise through *dialogue* between students' mathematic knowledge and the knowledge of professional math educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* learning.	Following initial equivalent fraction introduction at the school, students generate and write down words\ideas about equivalent fractions.	This session will be led by an inter-disciplinary team of drama and math educators who lead a process to generate students' questions.	Experimenting with various drama techniques.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data in the form of mathematical examples. These may come from *individual, collaborative and communal activity* such as practical work (idea generations).	Students engage in practical activities (such as for example division of physical artefacts).	Explain the mathematical concepts, support the process of dividing physical artefacts.	The art activities are embedded in students' attention to e.g. visual detail when dividing physical artefacts and/or the use of the resulting divided artefacts as visual elements in a potential dramatic performance at the school.
Phase 3: **ANALYSE:** students analyze evidence	Students analyze mathematical, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyze examples and make conclusions regarding their own initiative.	Help students interpret the potential implications of the examples for the students' own inquiry.	Begin creating and rehearsing the drama while taking inspiration from the math examples

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Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use their mathematical examples they've generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of mathematical explanations.	Guide students in their consideration of possibilities.	Continued production of original material (e.g. script) and beginning drama rehearsals in the case of a performance.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with mathematical knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge (art/science) to understand the origin of their ideas and reflect on the strength of their examples and explanations in relation to the original question.	Formulating ideas in relation to discipline knowledge (math) in a larger context, including how mathematic and artistic ideas may cross-fertilize each other within the inquiry process.	Ensure mathematic quality with regard to explanations and examples.	Continued rehearsals, costumes making.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with math educators, offers students the chance to test their new thinking and experience and be *immersed* in a key part of the mathematical process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications (working with others).	Supports the communication process and the	Performing the drama: Possible to invite parents, other teachers, etc.

			drama performance logistics	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the mathematic and artistic conclusions.	Facilitates the reflection process. E.g. guiding the students with regard to working together, applying activities.	Reflection on the process, and collection of documentation of data to the extent possible / performance of the drama.

6. Additional Information

The 1-day demonstrator may be extended to include a more in-depth exploration of specific details such as a single equation or mathematical exercise. Pupils may be challenged to explore how specific fractions may be dramatized. The following text provides ample opportunity for this. Drama-related questions are interweaved in the mathematical text, opening doors for new exercises…

8.1 Fraction terminology

The term **fraction** is used to refer to a number written in the form $\frac{a}{b}$ with $b \neq 0$. Children in the early grades use fractions whose numerators and denominators are whole numbers. In later grades, fractions whose numerators and denominators are integers and real numbers, may be encountered. In general, the numerator and denominator of a fraction can be any number as long as the denominator is not zero. *What kinds of dramatic sequences best represent integers? What kind of drama characters would support a dramatic sequence dealing with a fraction in which the numerator and denominator are the same number?*

9.2 The concept of fractions

Often, whole numbers do not fully describe a mathematical situation. As an example of this, using whole numbers, try to answer the following questions relating to Figure 1: How much pizza is left? How much of the stick is shaded? And how much paint is left in the can?

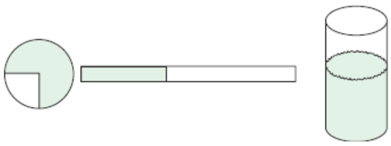


Figure1

Students need experiences that build on their informal fraction knowledge before they are introduced to fraction symbols. Although it is not easy to provide whole-number answers to the preceding questions, the situations in Figure 1 can be conveniently described using fractions. Reconsider the preceding questions while observing the subdivisions added in Figure 2. Typical answers to these questions are "three-fourths of the pizza is left," "four-tenths of the stick is shaded," and "the paint can is three-fifths full." While considering this new perspective, try to reflect on these drama-related questions: *What would be the difference between a dramatic sequence inspired by figure 1 and one inspired by figure 2?*

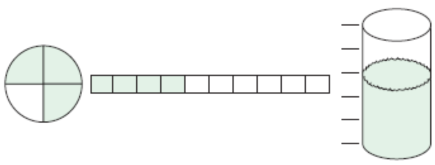
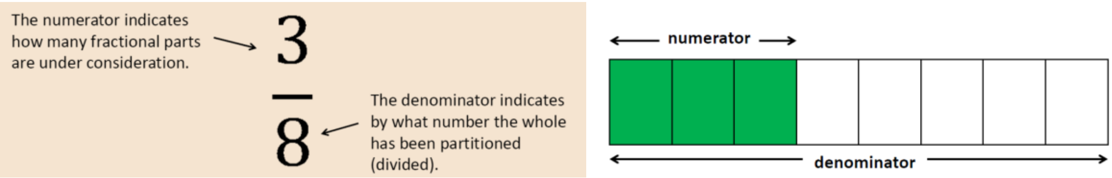


Figure 2

Indeed, the term *fraction* is used in two distinct ways in elementary mathematics. Initially, fractions are used as numerals to indicate the number of parts of a whole to be considered. In Figure 2, the pizza was cut into 4 equivalent pieces, and 3 remain. In this case, we use the fraction to represent the 3 out of 4 equivalent pieces. The use of a fraction as a numeral in this way is commonly called the "part to whole" model. If a and b are whole numbers, where $b \neq 0$, then the fraction $\frac{a}{b}$, represents a of b equivalent parts;

a is called the **numerator** and *b* is called the **denominator**. *Can numerators and denominators be represented by dramatic characters? How so? What would be the relationship between those characters in a drama sequence?*



The term *equivalent parts* means equivalent in some attribute, such as length, area, volume, number, or weight, depending on the composition of the whole and appropriate parts. In Figure 2, since 4 of 10 equivalent parts of the stick are shaded, the fraction $\frac{4}{10}$ describes the shaded part when it is compared to the whole stick. Also, the fraction $\frac{3}{5}$ describes the filled portion of the paint can in Figure 2.

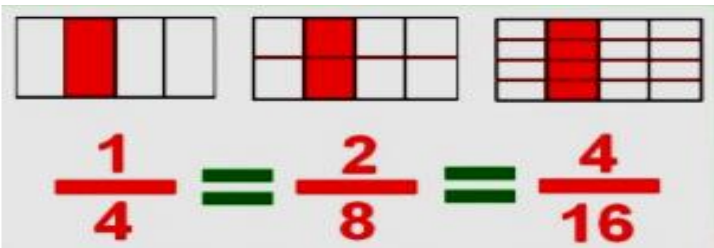
Part to Whole Concept: The most common use of fractions involves the **part-to-whole concept,** that is, the use of a fraction to denote part of a whole. In the fraction $\frac{a}{b}$, the bottom number *b* indicates the number of equal parts in a whole, and the top number *a* indicates the number of parts being considered. The part to whole concept of a fraction also is used in describing part of a set of individual objects. *What kind of dramaturgical ideas may be developed based on the Part to Whole concept?*

Equivalent Fractions

Developing an Equivalent Fraction Algorithm

When students understand that fractions can have different (but equivalent) names, they are ready to develop a method for finding equivalent names for a particular value. An area model is a good visual for connecting the concept of equivalence to the standard algorithm for finding equivalent fractions (multiply both the top and bottom numbers by the same number to get an equivalent fraction). The approach suggested here is to look for a pattern in the way that the fractional parts in both the part and the whole are counted. *How can this approach be represented by drama characters? What kind of characters would best support this? Why?*

The following figure show geometric visualization of equivalent fractions $\frac{1}{4} = \frac{2}{8} = \frac{4}{16}$.



It is easy to show the above fractions are equal using equivalent fraction algorithm. Multiplying both the numerator and the denominator by the same number we have

$$\frac{1}{4} = \frac{1 \cdot 2}{4 \cdot 2} = \frac{2}{8}, \qquad \frac{1}{4} = \frac{1 \cdot 4}{4 \cdot 4} = \frac{4}{16}.$$

Hence the fractions $\frac{1}{4}$, $\frac{2}{8}$, and $\frac{4}{16}$ are equivalent fractions. *Can numerators and denominators be represented by dramatic characters? How so? What kind of personalities would those characters have? Why?*

Example: Find 7 fractions equivalent to the fraction $\frac{3}{4}$.

Solution: Using the algorithm we can find many different fractions equivalent to the fraction $\frac{3}{4}$ by multiplying both the numerator and the denominator by the same number.

$\frac{3}{4} = \frac{6}{8} = \frac{9}{12} = \frac{12}{16} = \frac{15}{20} = \frac{18}{24} = \frac{21}{28} = \frac{24}{32}$, are equivalent fractions to the fraction $\frac{3}{4}$.

Example: Show that $\frac{2}{3} = \frac{8}{12}$ are equivalent fractions using equivalent fraction algorithm and visualization.

Solution: i) $\frac{2}{3} = \frac{2 \cdot 4}{3 \cdot 4} = \frac{8}{12}$, multiplying both the numerator and the denominator by 4.

ii) We can see from the two rectangles the shaded regions are equal. The two fractions represent equivalent fractions.

Therefore $\frac{2}{3}$ *and* $\frac{8}{12}$ are equivalent fractions as shown using equivalent fraction algorithm and visualization.

Example: Use models to show that the following fractions are equivalent.

a. $\frac{1}{3} = \frac{2}{6}$ b. $\frac{1}{2} = \frac{2}{4}$

Solution:

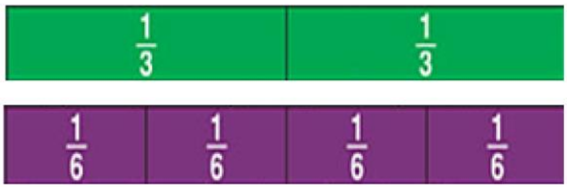


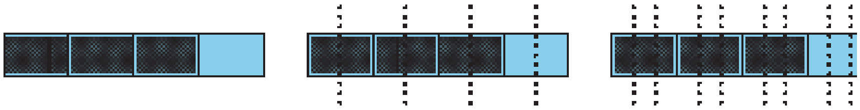
Figure 10

We can see from figure 10 that the fraction $\frac{1}{3}$ in the first part is divided in to two equal parts each $\frac{1}{6}$ in the second rectangle. So $\frac{1}{6} + \frac{1}{6} = \frac{2}{6}$. So we can say that the two fractions are equivalent as shown above. On the number line model we can see that $\frac{1}{2}$ and $\frac{2}{4}$ have the same place on the number line. *What would be the relationships between characters representing* $\frac{1}{2}$ *and* $\frac{2}{4}$ *?*

For every fraction there are an infinite number of other fractions that represent the same number. The fraction Bars in Figure 11 show one method of obtaining fractions equal to $\frac{3}{4}$.

In part b, each part of the $\frac{3}{4}$ bar has been split into 2 equal parts to show that $\frac{3}{4} = \frac{6}{8}$. We see that doubling the number of parts in a bar also doubles the number of shaded parts. This is equivalent to multiplying both the numerator and denominator of $\frac{3}{4}$ by 2. Similarly, part c shows that splitting each part of $\frac{3}{4}$ bar into 3 equal parts triples the number of parts in the bar and triples the number of shaded

parts. This has the effect of multiplying both the numerator and denominator of $\frac{3}{4}$ by 3 and shows that $\frac{3}{4}$ is equal to $\frac{9}{12}$. *How can the fraction Bar contribute to the scenography of a drama performance which is part of a creative inquiry?*



$\frac{3}{4} = \frac{2.3}{2.4} = \frac{6}{8}$ $\frac{3}{4} = \frac{3.3}{3.4} = \frac{9}{12}$

a) b) c)

Figure 11

The examples in Figure 11 illustrate the *fundamental rule for equality of fractions:* For any fraction, an **equal fraction** will be obtained by multiplying the numerator and denominator by a nonzero number.

Fundamental Rule for Equality of Fractions

For any fraction $\frac{a}{b}$ and any number $k \neq 0$, $\frac{a}{b} = \frac{k \cdot a}{k \cdot b}$.

An understanding of equivalence of fractions is important in developing sense of relative size of fractions and helping students connect their intuitive understandings to more general methods Musser, Burger, Peterson 2008).

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7. Assessment

The assessment is based on three main procedures: The CREATIONS project's assessment (pre and post implementation); the school may also choose to do additional assessments of the project.

CREATIONS implementations are assessed by both pupils and teachers. Evaluation analytics will show the effectiveness and efficiency of employing creative teaching approaches. The web analysis will be used to show a change in the users-behaviour. The evaluation approach of the CREATIONS project will use both qualitative and quantitative approaches. The umbrella question is: ***can the implementation of the*** **CREATIONS** ***approach influence motivation for STEM?***

Further details:

- Teachers fill out a short questionnaire (VALNET) regarding the impact of CREATIONS activities on the curricula. This will support the connection of CREATIONS with different schools and policy makers. In Norwegian, the link to this questionnaire is:
- Pupils fill out questionnaires pre- and post-intervention (Science Motivation Questionnaire (SMQ). These are available in Norwegian and are sent to the school's head teacher for the pupils to fill.

8. Possible Extension

Possible extensions may include the adaptation of this demonstrator's approach to other areas of mathematics such as percentages, prime numbers, odds and evens, etc.

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CREATIONS has received funding from the European Commission HORIZON2020 Programme

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrator**

D3.2.49 Moon Village

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Oded Ben-Horin (Western Norway University of Applied Sciences)
Code:	D 3.2.49.	**Contributors:**	
Version & Date:	2.0 / June 1st, 2018	**Approved by:NKUA**	

Figure 2: Image Credit ESA (https://www.google.no/search?q=images+of+moon+village+esa&biw=1617&bih=739&tbm=isch&imgil=Iw_pfimQr4BNYM%253A%253BJ8pidW22_YPUiM%253Bhttp%25253A%25252F%25252Fwww.space.com%25252F32695-moon-colony-european-space-agency.html&source=iu&p)

1. Introduction/ Demonstrator Identity

1.1 Subject Domain

Astronomy, and specifically the technological and social innovations related to the creation of a Moon Village.

1.2 Type of Activity

"Moon Village" is a trans-disciplinary creative education initiative enabled through digital interactions, implemented on a global scale in the framework of Global Science Opera. «Moon Village» builds upon previous Global Science Opera productions and extends their scope in in that the "Moon Village" dramatic structure aims to itself *become part of the European development and realization of the Moon Village vision*. In this framework, the "Moon Village" dramaturgy addresses specific questions related to societal challenges awaiting a future permanent community ("village") on the Moon. The arts-infused scientific inquiry thus allows participating pupils to take part in the development of a complex inquiry with scientific, technological and social implications.

1.3 Duration

During a period stretching over several months, teachers in the various countries choose to dedicate time according to their capacities, and their roles in the opera (e.g. performers, composers, etc.).

The premier opera performance (December 13th, 2017) lasted for 1 hour.

1.4 Setting (formal / informal learning)

"Moon Village", building upon the Global Science Opera tradition, is open to any kind of educational frameworks. Performing parties are schools which have integrated the GSO into their activities, universities, or art education institutions.

1.5 Effective Learning Environment

"Moon Village" relates to the following categorization (please see CREATIONS D2.3 for further details):

- **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art.
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work, and in this case, the European Space Agency.
- **Communities of practice (web-based/physical)** as a network of online communities.
- **Communication of scientific ideas to audience** addressing the need to establish settings in which learners are invited to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.).

2 Rational of the Activity / Educational Approach

2.1 Challenge

The European vision of a future Moon Village is an ambitious one. It will rely on innovation in many disciplines at the same time as its realization will have social implications here on Earth. Therefore, there is a need to create broad social engagement in this process. To this aim, pupils' challenges of engaging with questions of physics, astronomy and society, are hereby addressed: the specific challenges addressed are the abstract and "non-tangible" nature of the Moon Village in today's classrooms.

2.2 Added Value

"Moon Village", by building upon the Global Science Opera traditions, allows a global network of schools, universities and art institutions to join hands and co-create together. Through this, the creation of this science opera enables a global network to deal with specific, concrete and real questions about a futuristic and, as of yet, non-tangible scientific theme. In "Moon Village", the participating pupils dealt primarily with the question of how a potential future education for children born on the Moon Village, may be conceptualized and implemented, as a direct consequence of the scientific realities, challenges and opportunities which the Moon Village will entail. An added value is thus the creation of a creative, global educational space in which to discuss and explore these issues.

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3 Learning Objectives

3.1 Domain specific objectives

The scientific domain is astronomy and the ESA's Moon Village[22].

Note: pupil ages vary from country to country, meaning that learning objectives may be adapted locally by each school. All schools, though, learn about the Moon Village and its related science and technology, as a common theme.

3.2 General skills objectives

The objective of skills may be seen as developing social and emotional skills, cognitive skills, and, especially, meeting points between these, within an international context. Creativity and critical thinking, both considered to be "21st century skills", may largely be said to occur in the interaction, and cross-fertilization between these groups of skills (OECD, 2015).

[22] https://www.youtube.com/watch?v=amYK5voqLSk&feature=youtu.be

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to describe the methodology for implementation of the "Moon Village" framework of Global Science Opera.

4.2 Student needs addressed

There is a need to address the intangible, futuristic and abstract nature of the scientific and social topic explored in this demonstrator, and to concretize the Moon Village vision and implications within the (science) classroom. This, in order to deal with specific scientific inquiries related to the Moon Village, exemplified by questions relating to gravity, radiation, sustainability, and more.

5 Learning Activities & Effective Learning Environments

During the "Moon Village" opera production, performers, composers, designers, scenographers, science educators, etc., collaborate to create the opera. There is no "one size fits all" approach. Typically, a school will receive a scene in the opera, which they will write the libretto for following their exploration of the scientific theme at hand. Then they will compose music for it, and perform that scene by video or online, as part of a global community.

Science topic: Astronomy and Technology (Relevance to national curriculum) Class information Year Group: open to all grades. Most classes are 5th grade or higher. Age range: open to all ages. Most pupils are of age 10 and older Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate. Each teacher is responsible for connecting the scientific theme to the level of his/her pupils, with a focus on science and/or art, according to the educator's specialization, yet all participate in both exploratory processes to various degrees. "Moon Village" is open to pupils with disabilities, and the Dutch team has focused on involving pupils with disabilities in the project.	Materials and Resources *What do you need?* Performers will need access to video and/or streaming facilities, as well as costumes. Composers need access to music lessons and instruments. All participants need access to high level scientific information, which is continuously in dialogue with scientists and science educators. *Where will the learning take place?* Each class will decide this for themselves. Most learning will take place in the classroom, in labs, or in a local arts institution. *Health and Safety implications?* No. *Technology?* Yes. Taking part in the rehearsals and streaming (for countries performing live) involves access to internet. *Teacher support?* Both science and art teacher support is needed. Contact with teachers or professionals within the other discipline(s), or collaboration with one of the other teams in order to make up for the lacking capacity in that specific school/university, is strongly encouraged.

Prior pupil knowledge
Individual session project objectives*:* The "Moon Village" production is an opportunity for students to explore issues related to astronomy and technology. These topics set the inquiry process for the opera in motion. "Moon Village" is focused on science inquiry in a creative framework. Also, science communication is a major factor by allowing a scientific theme to inspire a multi-disciplinary artistic project's outputs. The project allows students to interact and develop social and collaboration skills, thus experiencing how science can be a group activity and not only a solitary one: this takes place within the added digital dimension, in which pupils take part in a "Global Classroom" with other pupils around the world. Specifically, the following aims are present: ➢ Active participation in the negotiation of scientific concepts ➢ Developing creative skills based on the CREATIONS inquiry approach ➢ Understanding of scientific concepts and phenomena ➢ Scientific interconnection of science with aspects of art (students will undergo a multi-disciplinary artistic process which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines). ➢ Developing a cross-country, multi-cultural spirit of friendship, cooperation and teamwork ➢ Digital competences and their social impacts Connecting the science classroom with research infrastructures

Assessment	**Differentiation**	**Key Concepts and Terminology**
"Moon Village" relies on the CREATIONS project assessment approach of Scientific Motivation Questionnaires. In addition, and in	*How can the activities be adapted to the needs of individual pupils?*	**Science terminology:** Astronomy, Moon, Solar System, Space

order to enhance this approach and gain further knowledge, the CREATIONS project liaises with other initiatives which explore various qualitative aspects of the "Moon Village" with respect to both pupils, teachers, and organizers.	"Moon Village" provides a framework which needs local adaptation with regard to language, age group, and individual pupils' interests in various disciplines (e.g. music, visual arts).	**Arts terminology:** 1) Aria: Solo song by one character. The plot's "action" is stopped to allow this character to express a certain emotion and inner feelings. 2) Duet: Two singers, preferably each singing their own verse followed by a section in which they sing together. 3) Ensembles: Three or more singers 4) Choir: The choir can be used to "comment" during the other songs, or as simple choir pieces. 5) Overture: Instrumental (no voices) opening piece which sets the mood of the opera. 6) Interlude: Music performed between acts or scenes.
Session Objectives: During this scenario, students will Explore the ESA website, and learn about modern research concerning the Moon Village; Experience musical, visual design, drama techniques as tools for the opera; be introduced to pupils from other countries.		

Students gain knowledge and experience with group-work in which various groups will create compositions, scenography, costumes for the Science Opera. The libretto includes key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.

Throughout the scenario, pupils learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONS Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning.	Generates questions about the moon and solar system.	Introduces the topic of "Moon Village" by (for example) watching the European Space Agency's video. [23]	Begin cooperation with music/fine arts/drama/dance teacher(s). Examples: experimenting with various musical instruments and

[23] https://www.youtube.com/watch?v=amYK5voqLSk&feature=youtu.be

				drama techniques.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity.	Students compare their ideas to existing evidence.	Guides students to relevant evidence.	Comparing artistic ideas to other art-works, especially school art works created by pupils. Give preference to art projects inspired by scientific phenomena.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse evidence and make conclusions. This process is crucial to understanding the connection between scientific discovery and the artistic process.	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin creating and rehearsing the opera.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of scientific explanations, and sharing ideas with GSO schools in other countries	Guide students in their consideration of possibilities.	Continued production of original material (music, etc.), and opera rehearsals, and awareness of what students in other countries are developing.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and artistic ideas may cross-fertilize each other within the inquiry process.	Ensure scientific quality with regard to explanations	Continued rehearsals, costumes making. Rehearsals may take place with other countries at this stage.
Phase 6: **COMMUNICATE:** students	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process.	Students communicate their knowledge and explore its ethical implications.	Supports the communication process and the opera	Opera performance locally and online (streaming)

communicate and justify explanation			performance logistics	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding scientific and artistic conclusions	Discuss the implications of a global collaboration with students	Reflection on the process, and collection of documentation of data from the event to the extent possible / sharing experiences via social media.

6 Additional Information

Website: www.globalscienceopera.com

7 Assessment

During the "Moon Village" production, schools were invited to take part in the CREATIONS evaluation process (2nd half of 2017) for pupils (pre- and post) and teachers (post).

Furthermore, additional qualitative assessments regarding the initiative's design, is developed through dialogue with additional research projects with which the CREATIONS project liaises.

8 Possible Extension

The "Moon Village" opera may be extended to various scientific themes, by allowing participating pupils to develop inquiry-based questions which are designed to specifically be part in, and contribute to, currently ongoing scientific explorations. The inclusion of arts-education activities in the project opens doors to enabling this approach.

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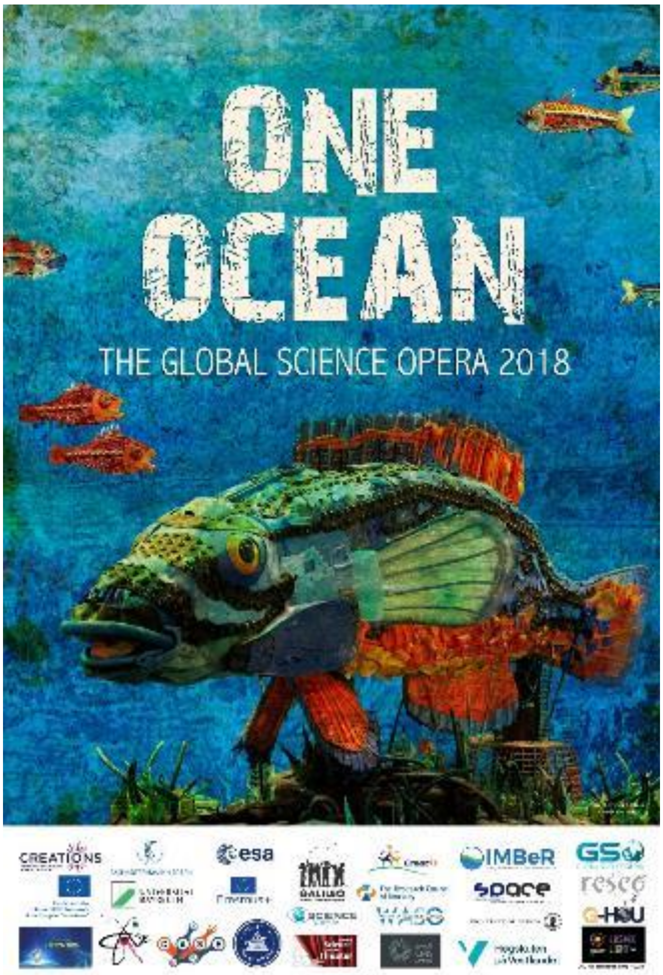
CREATIONS has received funding from the European Commission HORIZON2020 Programme

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.50 Sustainable Design – Ecoscenography and Creativity in the Global Science Opera

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:** Janne Robberstad and Oded Ben-Horin (Western Norway University of Applied Sciences (HVL)	
Code:	D 3.2.50.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	



CREATIONS has received funding from the European Commission HORIZON2020 Programme

1. Introduction / Demonstrator Identity

This demonstrator is based on the work planned for the author's PhD work in the years 2018-2022.

1.1 Subject Domain

Sustainability, Eco-systems (oceans)

1.2 Type of Activity

International activity.

- Educational activities based on Creativity-enriched Inquiry Based Approaches (school based)
- Educational Activities that promote school- research center collaboration

1.3 Duration

The process of creating a GSO production, including the work with the ecoscenography, lasts for approximately 10 months. Creating an ecoscenography (set, costumes, lights, etc.) for their scene is intended to be an integrated part of the pre-production plan in every participating school. Note that ecoscenography intends work after the performance, to secure a sustainable after-life for the set, costumes, etc.

Teacher showing student how to crochet with used, cut-up plastic-bags. Her work will become part of her costume.

1.4 Setting (formal / informal learning)

Formal and informal.

Note: Ecoscenography is open to all kinds of educational frameworks formal and informal. Most of the participants are schools from primary- to university-level, whom have integrated the GSO into their activities. However, some participating schools have based their activity in their community outreach programs.

1.5 Effective Learning Environment

This demonstrator relates to the following categorization (please see CREATIONS D2.3 for further details):

- ***Arts-based*** *which addresses and enhances scientific interconnection of science with aspects of art*
- ***Sustainability,*** aiming to engage students in awareness-building and provide them with tools of knowledge with which to meet future ecological challenges.
- ***Dialogic space / argumentation*** *aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work*
- ***Communities of practice (web-based/physical)*** *aiming to develop a network of online communities and channels sharing multicast-activities inspired by science and sustainability on national or international level.*
- ***Communication of scientific and sustainable ideas to audience*** *addressing the need to establish settings in which learners will be enhanced to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.); promoting this way a dual channel of communication: a) reflective processes (self-engagement for scientific consistency and verification) and b) explicit elaboration of scientific ideas through interaction and 'extroversion'.*

The ecoscenography approach in GSO is to communicate with "alpha-contacts" in each country, who thereafter engage institutions in their countries. For this reason, there has been a wide diversity in the approach to implementation, and to what effective learning environments represent.

- Global environment: Digital platform (Adobe Connect for meetings/rehearsals, and live-streaming for performance), cross-cultural collaboration and direct contact between participating countries.
- Local environment: School, university, art institution or research center

CREATIONS has received funding from the European Commission HORIZON2020 Programme

A student showing her finished jelly-fish, made from a used plastic water-bottle.

2. Rational of the Activity / Educational Approach

2.1 Challenge

The challenge for students is to understand the consequences of pollution in a tangible way. Furthermore, the issue of oceans' sustainability is very large. Currently, there is a need for additional ways to enabling students to understand that they do, indeed, have the potential to act and make a difference.

2.2 Added Value

All ecoscenography workshops (within GSO) are inquiry-based science educational, with equal emphasis on science and arts. The creative process is essential, cooperative and democratic. The collaboration is international and is respectful of cultures and is adaptable to local variables.

The GSO ecoscenography teaching-material is intended to be adjustable and accommodate local variables like age, language and cultural differences, and adaptable to different scientific themes. It is particularly important to consider local geographical variables, as ecoscenography favors short-traveled materials and eco-clarity.

The challenge is to jointly implement the methods of Ecoscenography and GSO with a sustainable and robust design adaptable to all these variables on a global scale. (Van den Akker, Gravemeijer, McKenney, & Nieveen, 2006).

Relevance for RRI *(von Schomberg 2011b,* European Commission*)*: the Ecoscenography-workshops relate to the intersection of art and science within a global framework characterized by cross-country and cross-cultural collaboration. This will be exemplified through the exploration of a potential capacity to introduce a mindset of *sustainability* in educational systems (schools) within the creative art-and-science context and the inter-relationships which the theme of sustainability may have with the *kind* of creativity which GSO enables.

GSO necessitates Possibility Thinking (see CREATIONS Deliverable 2.1), as it requires the invention of solutions for a variety of artistic, science education and technological procedures. Also, for school pupils, preliminary data has shown that the concept of "performing in front of the whole world" provides a growing opportunity.

Ecoscenography is based on the philosophy of Deep Ecology, which advocates that humans are *part of* the biodiversity of life on earth, *not* at the top of the hierarchy-pyramid. All life, for all generations, has equal right to live and thrive. This means that we need to take care of the earth, using it sustainably, so that future generations also may live and thrive on Earth[24]. It also means going deeper than eco-efficiency.

Within the GSO, ecoscenography binds together the joint efforts of a global cooperation, a trans-disciplinary collaboration of science and arts, an educational initiative equipping young people with tools of knowledge.

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[24] In 1987, the **UN** Brundtland Commission **defined sustainable** development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." (Report of the World Commission on Environment and Development.)

Ecoscenography is a simple, yet complex effort. It´s goal is easy to proclaim, but the road to reach that goal may be less obvious. It lies in the cross-section between science and arts, between sustainability and design, aesthetics and engineering, artistry and craftsmanship.

In the tradition of the GSO, students are meant to participate in the whole process of ecoscenography, from idea, design, production, event and afterlife.

Note: There are some challenges with conducting an ecoscenography. The main one is how our society is conventionally deisgned to use nos-sustainable materials and designs. So building awareness in the local communities as one works with sustainable design, is an important part and/or side-effect of working with sustainable design.

The teacher´s lack of training in sustainable design may be another challenge, as eco-design can be rather complex. However, one can get a long way with basic knowledge, and more know-how will accumulate with experience.

Another issue is funding, as arts and crafts actually need materials and equipment in order to make a product. It is difficult to create something from nothing. It is possible to recycle waste-materials, but even then some funding may be required.

There is also the challenge of time. Schools are weighed down with a tight schedule and a large curriculum, which might affect the possibility of leaving enough time to see a good ecoscenography workshop through.

The students themselves however are often very engaged in their own future and concider climate change a crucial part of it, so they welcome the chance to learn about sustainability in a hand-on matter.

3. Learning Objectives

3.1 Domain specific objectives

Eco-scenography within the context of GSO requires insight into both the arts and science, the two main fields in this transdisciplinary collaboration, and therefore complements both fields of expertise. It will provide the bridge between the two fields, as a foundation for a *trans-disciplinary* collaboration (Robberstad, 2017).

Eco-scenography's relevance in this perspective is three-fold. Firstly, it provides **a link between the disciplines of arts and science**, based on the pupils´ *dependency* on knowledge and skills from both fields in order to create a successful design (thus far, this has only been introduced on a miniscule scale within GSO. Through further iterative implementation, research will provide recommendations as to its potentials). Secondly, it provides **a bridge between theory and practice from within the RRI framework** and thus providing concrete evidence of global classrooms' affordances within a central European policy initiative. Thirdly, Eco-scenography, while opening doors to creative work in its own right, here also **corresponds to the global challenge of the question of sustainability**.

Due to the fact that GSO pupil ages often vary from country to country, learning objectives must be defined locally by each school so as to engage in questions inspiring inquiry in this field (Chappell et al, 2016). In arts education, the objectives are to learn sustainable design as a methodology, including specific skills and inquiry with the various included arts education domains (set, costume, lighting-design, etc.).

Specific objectives are to

- get students interested/engaged in science and research, seeing the necessity of sustainable development in the age of the Anthropocene.
- get students interested/engaged in arts & crafts, seeing the creative potential that can be developed through this particular field.
- get students interested/engaged in sustainability, enabling them into action towards a healthier future for people, planet and profit with peace and partnership (UN, 2015).
- show students how one can generate a new level of creativity by asking the simple question: how can I make this sustainable? (/Is this sustainable?)
- introduce ways of thinking that are easily transferable to other areas of life.
- introduce students to the eco-efficiency -"motto" of re-duce, re-use, re-cycle, and expand it with re-think, re-imagine and re-generate (Hes & DuPlessis, 2014; Beer, 2016). (Sustainable innovation is an ecological worldview that suggests a more positive and inspiring legacy than the sacrifice-focused eco-efficiency.)
- introduce practical techniques and sustainable materials in the production of a real-life, international opera-setting (GSO)

3.2 General skills objectives

The objective of skills may be seen as developing ethical, social and emotional skills, cognitive skills, and, especially, meeting points between these, within an international context. Sustainability and creativity, both

considered to be "21st century skills", may largely be said to occur in the interaction, and cross-fertilization between these groups of skills (OECD, 2015 - need correct reference here).

More specifically, learning across boundaries, inquiry spanning over more than one school collaboratively, and practical skills, may be seen to be part of the inquiry process exemplified by ecoscenography in the GSO.

Sustainability can be included into the classic goals of design: function, form and finance. This is done by equipping students with skills and knowledge about complex and often contradictory issues regarding resources, social and ethical considerations, product life-cycles, etc. The majority of students participating worldwide in the GSO will not become professional designers when they grow up, but they *will* all be consumers (Deniz, 2016). And a growing ecological consciousness is essential for the earth´s future. This, in turn, also provides a direct connection to high-quality craftsmanship being taught in arts and crafts education.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Ecoscenography is a common term describing environmentally friendly theatre-design. Traditionally this includes set-, costume-, lighting-design, hair and make-up. But scenography is a wider term which includes all visual[25] communication with the audience from they enter the arena of an event. It is a word to describe the audience's complete experience with a show, short of the actual acting. In this demonstrator, the ecoscenography is set within the Global Science Opera initiative, and the examples used are placed within the 2018 production of GSO.

The Global Science Opera (GSO)[26] annual production in 2018 ("One Ocean") focuses on the ocean, sustainability and climate change. Inspired by Ocean Literacy[27], the opera communicates scientific knowledge about the ocean and the human-ocean relationship. Through both science and arts education activities (with special focus on arts and crafts in the current CREATIONS demonstrator), pupils engage with inquiry-based activities[28]. Ecoscenography thus builds a bridge between the two fields.

Sustainability, in relation to RRI, can be included in all aspects of the GSO production.

- It can be included as a scientific theme of its own, or as sub-theme, for the participants/students to work with.
- It can be used practically in the design-production
- It can communicate awareness or ethical questions to the audience

The aim of the demonstrator is to describe the GSO ecoscenography methodology for implementation, explore further its challenges and opportunities, receive rigorous feedback regarding this relatively new practice, and support its implementation within the CREATIONS project.

Sustainability can be included in all aspects of the GSO-production.

- It can be included as a scientific theme of its own, or as sub-theme, for the participants/students to work with.
- It can be used practically in the design-production
- It can communicate awareness or ethical questions to the audience

[25] scenography can also stimulate other senses: hear, smell, touch, taste

[26] www.globalscienceopera.com

[27] http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf

[28] IBSE (Inquiry Based Science Education) is designed especially to increase students´ interest in science and mathematics.

Students making jelly-fish made from used plastic water-bottles, to address plastic pollution in the ocean. The jelly-fish can be used both as props and as part of the set.

4.2 Student needs addressed

When meeting young people, they often express concern over the increasing manmade ecological challenges that will influence their future. This concern may enhance participating students in their engagement in the workshop. It appears that the combination of eco-scenography, creativity and the GSO strengthen each other in this educational intervention. Eco scenography acts as a bridge between science and arts, as knowledge from both areas are essential for a successful sustainable design. Furthermore it may engage the students in its transferability into other areas of their lives, being presented with the "tools" of eco design. The eco-creative process and the pedagogical theory of wise humanizing creativity (WHC)[29] process have in common working towards a higher goal: that of a common good for all life (Chappell et al,2016).

Eco-design is a common term describing design that takes into account the whole life-cycle of a product, considering environmental consequences from material resource-extraction, production, use, to the after-life. Inspired by nature itself, it seeks to eliminate the concept of waste. Eco-designers attempt to make the things we need with the thought in mind that nothing ever goes away (McDonough & Braungart, 2010).

Recognizing today´s wasteful practice of use-and-discard, the first step is to limit our consumption (eco-efficiency)[30]. But eco-design takes this one step further, positing that every product should also have a

[29] WHC observes creativity´s fundamental humanizing potential, the core concept of **"making and being made"** is a reciprocal relationship between a creation and it´s creator(s). One can experience personal changes when creating, by expressing and developing ones own voice, either by one self or with others, and by actively using the imagination to embody ideas. Ultimately engaging in the creative process is shaping your identity. Embodying the creative process will influence your identity through a "journey of becoming" (Chappell, Craft, Rolfe & Jobbins, 2012).

[30] First introduced by the World Business Council for Sustainable Development (WBCSD) in 1992

positive environmental outcome[31] (Beer, 2016). Ecoscenography is an environmentally friendly approach to theatre design, rooted in Næss´ deep ecology philosophy and pioneered by Tanja Beer (ibid).

In other words, implementing eco-scenography is NOT primarily about using waste as free material in an educational art-session. It is about awareness- and theoretical and practical knowledge building, in students, teachers and perhaps the audience. One of the options is to use recycled material in this awareness building. Another way can be to focus on quality craftsmanship and natural, quality materials. A third option may be to focus on versatility and adaptability in design. In all cases, there should be an educational session on life-cycle assessment of products: where do the materials come from and where do they go after the show.

[31] As a consequence of development already exceeding the earth´s ecological carrying capacity (Birkeland in Beer, 2016 p. 48)

5. Learning Activities & Effective Learning Environments

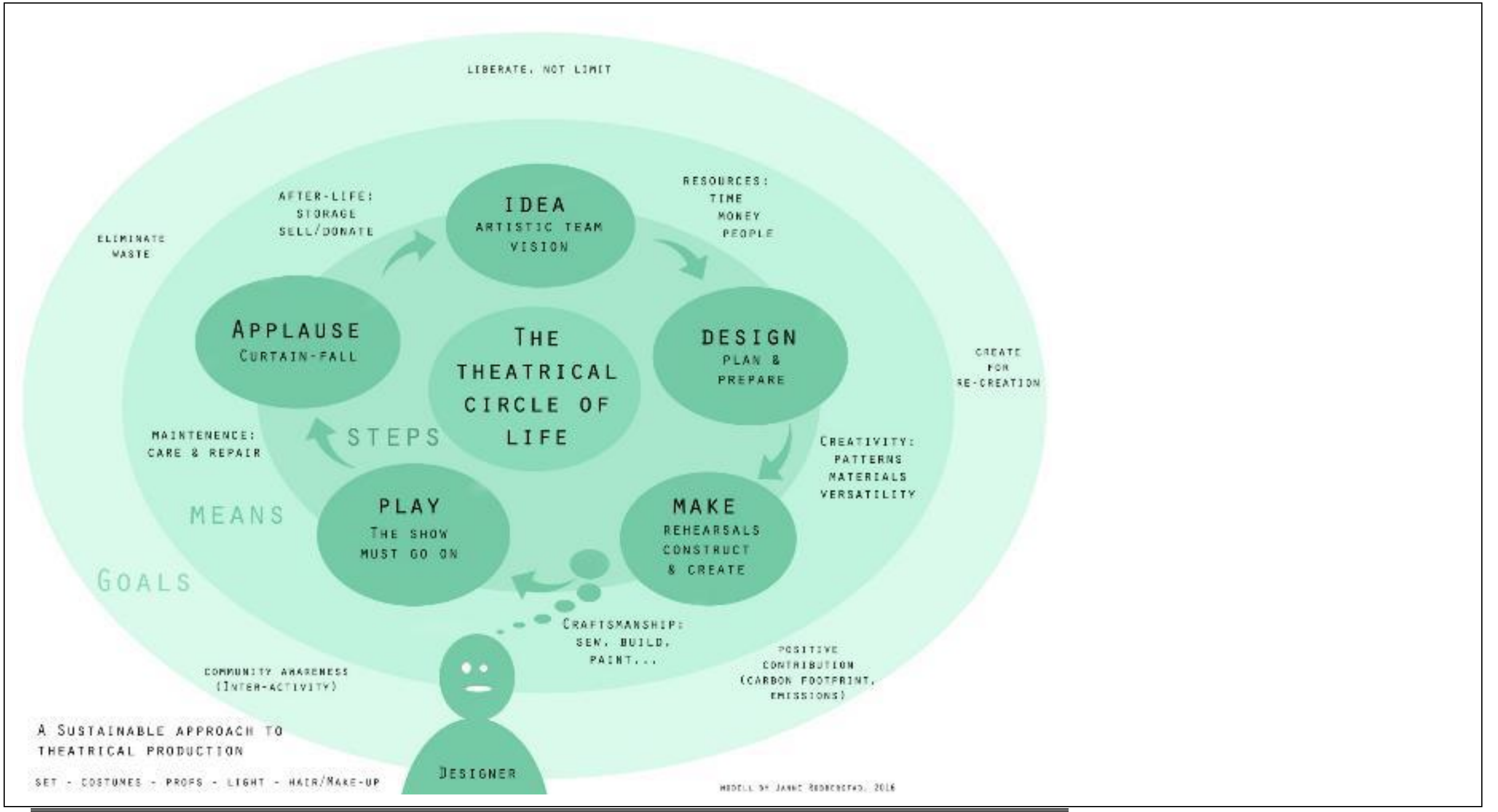
Ecoscenography Science topic: GSO 2018: Ocean, sustainability and climate change Relevance to (national) curriculum: UN´s sustainability goals[32] Class information: Ecoscenography is open to all ages. Most GSO-pupils are of age 10 and older Year Group: Age range: Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate. Each teacher is responsible for connecting the scientific theme to the level of his/her pupils, with a focus on both science and art, sustainability and design, all participate in both exploratory processes to various degrees. GSO ecoscenography is open to pupils with disabilities.	Materials and Resources: depends on chosen focus-area *What do you need?* This depends on the specific activity taking place in each school. All participants need access to high-level information on sustainable design. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* Space requirements: Room to create, literally and figuratively. *Health and Safety implications?* Avoid toxic materials. Apply techniques and equipment suitable for students' age and abilities. *Technology?* Depending on activity, various workshop equipment is needed. *Teacher support?* GSO has encouraged making contact with teachers or professionals within discipline(s) which the school does not access themselves, or collaboration with one of the other teams in order to make up for the lacking capacity in that specific school/university. Ecoscenography may initiate collaboration with community sustainability groups.

[32] https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Prior pupil knowledge: Students need no prior knowledge, but it is a big advance if the teacher(s) has prior knowledge regarding sustainable design. If not, the principles are easy to understand, and practical hands-on experience will quickly lead to a "know-how library".
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **Science topic:** Ocean, sustainability and climate change The GSO "One Ocean" scenario/production will be an opportunity for students to explore issues related to the ocean, sustainability and climate change. They will access the Ocean Literacy and can address further help from IMBeR[33], the main scientific collaborator for this opera. GSO is focused on science inquiry in a creative framework. When making an opera, the visual frames of the scenography is an essential part of the finished product. By implementing Ecoscenography one bridges the gap between science and arts, as one needs both in order to achieve a successful sustainable design (repetition). Ecoscenography includes the artistic areas of set, costume, lights, hair and make-up, posters and marketing, any other sensuous encounter aimed at the audience complete experience of the show (mentioned in intro). The project will also allow students to interact and develop social and collaboration skills, thus experiencing how science can be a group activity and not only a solitary one: Individual, collaborative and communal activities for change. This takes place also within the added digital dimension, in which pupils take part in a "Global Classroom" with other pupils around the world. Climate change knows no national borders, and global cooperation is important in our common struggle to deal with this challenge. By establishing a global educational collaboration at a young age, students will gain experience in cross-cultural team-work and collaboration, which in itself may induce hope for the future. Pupils will be introduced to the common creative impulses of science and the arts through ecoscenography. Specifically, the following aims are present:

[33] http://www.imber.info

- Active participation in the creative process of sustainable design and production (choosing artistic expression, materials, techniques, etc.)
- Developing creative design- and craft-skills and ecological knowledge (based on the CREATIONS inquiry approach)
- Understanding of scientific concepts and phenomena, especially connected to chemistry, engineering, biology, ecology, subjects needed to fulfill a successful sustainable design
- Scientific interconnection of science with aspects of art (students will undergo a multi-disciplinary artistic process which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines).
- (Developing a cross-country, multi-cultural spirit of friendship, cooperation and teamwork)
- Practical experience in international collaboration addressing a concern which needs global attention and cooperation.


LIBERATE, NOT LIMIT
AFTER-LIFE: STORAGE SELL/DONATE
IDEA
ARTISTIC TEAM VISION
RESOURCES: TIME MONEY PEOPLE
ELIMINATE WASTE
APPLAUSE
CURTAIN-FALL
THE THEATRICAL CIRCLE OF LIFE
DESIGN
PLAN & PREPARE
CREATE FOR RE-CREATION
MAINTENENCE: CARE & REPAIR
STEPS
CREATIVITY: PATTERNS MATERIALS VERSATILITY
MEANS
PLAY
THE SHOW MUST GO ON
MAKE
REHEARSALS CONSTRUCT & CREATE
GOALS
CRAFTSMANSHIP: SEW, BUILD, PAINT...
COMMUNITY AWARENESS (INTER-ACTIVITY)
POSITIVE CONTRIBUTION (CARBON FOOTPRINT, EMISSIONS)
A SUSTAINABLE APPROACH TO THEATRICAL PRODUCTION
SET - COSTUMES - PROPS - LIGHT - HAIR/MAKE-UP
DESIGNER

Assessment	**Differentiation**	**Key Concepts and Terminology**
The Eco-scenography capacity to engage students in science lessons will be assessed based on in-depth qualitative interviews conducted with focus groups in a variety of countries following their participation.	*How can the activities be adapted to the needs of individual pupils?* This is up to the local teachers. GSO provides a framework which needs local adaptation. In the future, it will be possible to develop GSO Ecoscenography for a specific age group, with a tailor-made curriculum focus.	**Science terminology:** Oceanography: the physical and biological properties and phenomena of the sea. Marine biology: the study of marine organisms, their behaviors and interactions with the environment. Marine pollution: harmful effects of chemicals, particles, industrial, agricultural, and residential waste, noise, or the spread of invasive organisms into the ocean.

		Arts terminology: Ecological terminology: Sustainable: to uphold the same level of something, keeping it people, planet, profit, partnership and peace-friendly. Climate change: a common term for changes in climate patterns caused by the increased levels of atmospheric carbon dioxide produced by use of fossil fuels. Anthropocene: current geological age, viewed as the period during which human activity has been dominant influence on climate and the environment. Deep Ecology: an environmental movement and philosophy which regards human life as just one of many equal components of a global ecosystem. Ecoscenographic terminology: Eco-design: creating products in a sustainable manner with special consideration for the environmental impacts of the product during its whole lifecycle. Life cycle assessment: the life cycle of a product is usually divided into procurement, manufacture, use, and disposal/afterlife. Set: visual theatrical scenery

		Costume: clothing worn to portray the wearer as a character at a social event in a theatrical performance on the stage. Lighting design: providing atmosphere and time of day for the production in response to the text, while keeping in mind issues of visibility, safety, and cost.

Session Objectives:

During this scenario, students will

Students will gain knowledge and experience with group-work in which various groups will design and create a complete ecoscenography for a GSO opera scene. By understanding the principles of sustainable design, they will be able to participate in creating a versatile ecologically friendly scenography.

By addressing both science and arts, students will learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes (IBSE).

By addressing the ecoscenography principles for sustainable design, students will learn how to design and create sustainably, reflect on the….

The model below show a life-cycle assessment of a theatrical production, stage by stage: Idea, Design, Make, Perform and After-life. Every department has different challenges and different solutions. The common idea is to look at two things: What comes in and what goes out. This can include a wide specter: materials, energy, copying-paper, food, the communication of the actors on stage, waste-management and storage, etc.

It is worth noting the importance of the idea- and design-stage. If you plan for a product to have several life-cycles already from the start, it is much easier to implement sustainability in the production.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinary* and personal, embodied learning.	Generate and writes down words\ideas about the ocean, sustainability and climate change, and shares with others in order to learn from	Activates previous knowledge in the fields of scientific exploration	Begin cooperation with arts & design and sustainability teacher(s) at your school in order to explore those subjects. Examples:

		their previous knowledge.		experimenting with various materials for scenographic "building blocks"
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts.	Students compare their ideas to existing evidence.	Guide students to relevant evidence.	Comparing conventional scenography to ecoscenographic works. Look at restrictions and possibilities
Phase 3: **ANALYSE:** students analyse evidence	Students analyze evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyze evidence and make conclusions regarding their own initiative	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin designing within the various ecoscenographic disciplines (set, costumes, lights, etc.)
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them.	Formulations of scientific explanations, and sharing ideas with	Guide students in their consideration of possibilities.	Production of original material (set, costumes, etc.), and

		GSO schools in other countries		expanding awareness of what other GSO students are developing.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and artistic ideas may cross-fertilize each other within the inquiry process.	Ensure scientific quality with regard to explanations	Continued creation.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications.	Supports the communication process and the opera performance logistics	Opera performance locally and online (streaming) with ecoscenograpic frames surrounding the scene

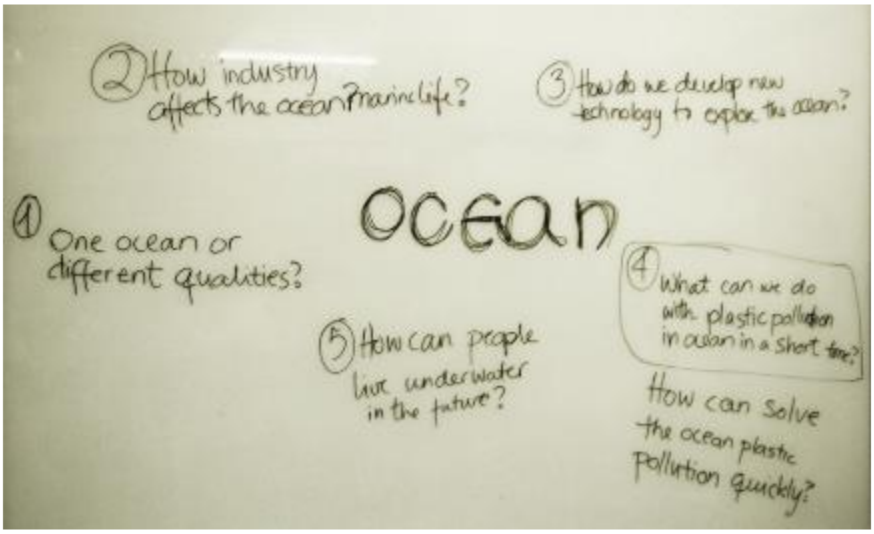
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the scientific and artistic conclusions	Discuss the implications of a global collaboration with students	Reflection on the process, and collection of documentation of data from the GSO event to the extent possible / sharing experiences via social media

6. Additional Information

"One Ocean" will premiere December 12th, 2018.

Website: www.globalscienceopera.com

Students painting with self-made egg-tempera and soil paint to illustrate the surface of the moon.



CREATIONS has received funding from the European Commission HORIZON2020 Programme

Examples of what students wonder about when learning about the Ocean, sustainability and climate change.

7. Assessment

There are various potential approaches to the assessment of the sustainable design activities.

The activity (demonstrator) lends itself to the CREATIONS project's assessment (pre and post implementation); the school may also choose to do additional assessments of the project.

CREATIONS implementations are assessed by both pupils and teachers. The evaluation approach of the CREATIONS project will use both qualitative and quantitative approaches. The umbrella question is: ***can the implementation of the* CREATIONS *approach influence motivation for STEM?***

Further details:

Teachers may fill out a short questionnaire (VALNET) regarding the impact of CREATIONS activities on the curricula. This will support the connection of CREATIONS with different schools and policy makers. In Norwegian, the link to this questionnaire is:

Pupils fill out questionnaires pre- and post-intervention (Science Motivation Questionnaire (SMQ). These are available in Norwegian and may be sent to the school's head teacher for the pupils to fill.

Furthermore, teachers may choose to, in collaboration with arts educators, assess the process and product of the activity based on the arts education process. Here it will be important to rely on the understandings and foci of the local arts educator in each school in which the activity is implemented.


Bamboo is a quick-growing, renewable resource, which with tape can be used as building-blocks in ever-new designs. Transparent sequins for costumes made from recycles water- and soda-bottles.

8. Possible Extension

The CREATIONS approach to inquiry has highlighted dialogue between science and the arts. Also, communal/community are a focal point. Within the scope of the GSO, it is possible to integrate these elements within the initiative's design to a greater extent. This entails bringing closer the various processes occurring in the different countries involved.

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All photos: Janne Robberstad

D3.2.51 Tjødnalio Community Culture Weeks: Astronomy

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Version & Date:	2.0 / Sept. 7th, 2017	**Approved by:NKUA**	

Community Culture Weeks: Astronomy

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy education spanning the complete spectrum of the Norwegian primary school (1st through 7th grades).

1.2 Type of Activity

Local educational activity based on Creativity-enriched Inquiry-Based Approaches (school based).

As an example, the main focus of the first implementation was on 40 pupils in the 4th-7th grades ("core group"), intertwined with the complete school exercising related activities based on a years-long "Culture Weeks" tradition of Tjødnalio School.

1.3 Duration

10 working days

1.4 Setting (formal / informal learning)

Formal learning on the premises of the school.

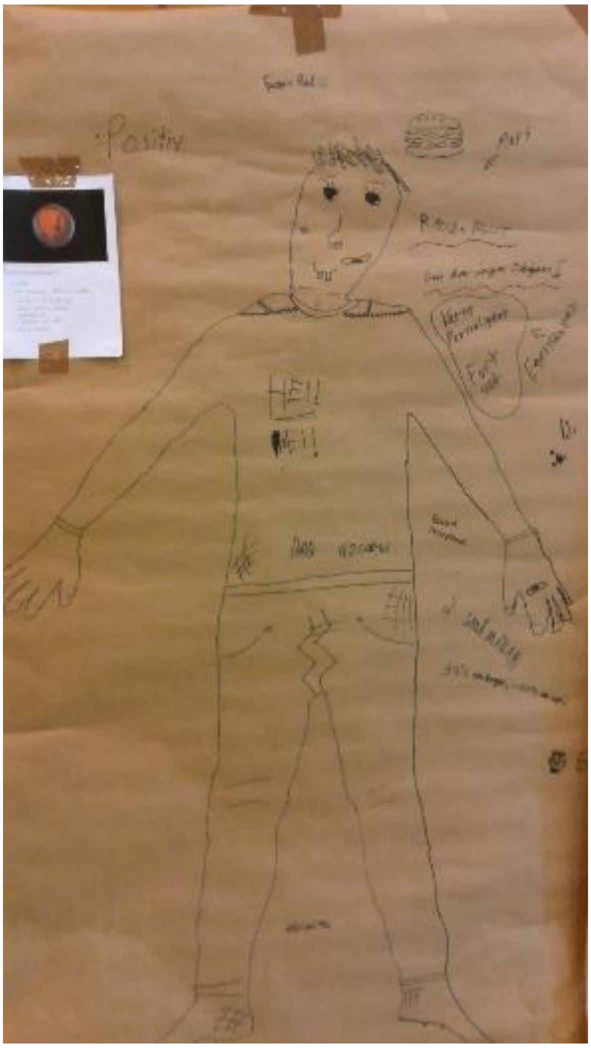
1.5 Effective Learning Environment

This demonstrator relates to the following categorizations (see CREATIONS D2.3 for further detail):

- **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art
- **Dialogic space / argumentation** aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

Note: The training described here includes elements of the Write a Science Opera (WASO) approach, yet that approach has here been adapted to renew its structure. Activity will take place with several teachers from Tjødnalio school (visual arts, music, science) and experts from the CREATIONS project partner, Western Norway University of Applied Sciences (music, science, drama).

CREATIONS has received funding from the European Commission HORIZON2020 Programme



Envisioning astronomy-inspired opera characters

The learning environment is collaborative and creative. It includes much movement (e.g. drama exercises). Approximately halfway through the project, the participating pupils in the "opera group" (approx. 40 in number) are divided into groups to create an "opera company" (orchestra, PR group, singers, light specialists, etc.).

2. Rationale of the Activity / Educational Approach

2.1 Challenge

The main challenge which this demonstrator addresses relates to a general lack of opportunity in schools for the science classroom to be experienced as an engaging element in an open community. This demonstrator literally "opens the doors" of the creative science classroom to the local community, employing the arts education elements as bridges between that classroom and the community.

The Demonstrator offers a creative design which stimulates creativity in the Inquiry-Based Science Education (IBSE) setting. It responds to challenges in today's schools regarding the rate of uptake of IBSE, and the strengthening of creative approaches to teaching in order to explore a strengthened engagement in science lessons.

2.2 Added Value

In response to the challenges presented above, this demonstrator builds upon a years' long tradition at the Tjødnalio school at Stord, Norway. Namely, an infrastructure for the involvement of the community in the classroom. Specifically, the Demonstrator provides learning opportunities in which pupils may cross-inspire and learn from and with each other in a creative school environment. Based on workshops and meetings implemented prior to the work with pupils, teachers gain techniques to support their ability to engage pupils in science inquiry in new, creative ways. Pupils are able to explore scientific questions through drama, music and visual arts. In this way they will gain access to the scientific material which is being taught from a large variety of perspectives.

Specifically, there are following added values to this approach: The designing of activities with a "core group" (in this case 40 pupils) which explore the science curriculum *deeply* through an artistic/operatic form, and allowing that group to interact with the rest of the school (in this case about 200 other pupils), provides the *complete school and revolving community* with an understanding, intuition and respect for arts integration and its capacities in education.

3. Learning Objectives

3.1 Domain specific objectives

The demonstrator's domain-specific objectives are to:

- Choice of specific scientific topic (e.g. supernova) conducted in an emergent way, together with the pupils in the "core" group, and simultaneously with their attending the activity stations ("stasjonar").
- To learn school opera as a methodology, including specific skills and inquiry with the various included arts education domains (music, drama, scenography, light design, etc.).
- Open the school by engaging the complete community (parents, etc.) in the product and thus the process.
- Finalize and perform a multi-disciplinary artistic performance (school opera) which demonstrates and deepens scientific and emotional understanding of the learning processes, supporting discipline knowledge in both the science and arts.
- Engage in activities which inspire curiosity around Astronomy; Explore musical, visual design, drama techniques as tools.
- Gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the Science Opera, accompanied by a continued exploration of astronomy: Pupils will learn to create specific synopsis, libretto, composition, scenography, costumes for the opera performance. *The libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music.*

3.2 General skills objectives

Specific skills:

- Active participation in the negotiation of scientific concepts with others
- Understanding of scientific concepts and phenomena
- Understanding the potential of meeting points of science with art
- Cooperation and teamwork

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to provide secondary and high schools with a methodology for implementation of the Tjødnalio Culture Weeks. This entails creating a science opera as a "core group", allowing the complete school to interact with that science opera through e.g. the participation through a single song, a visual art exhibition, etc. and the opening of the school's doors to the community.

This activity necessitates the presence of a group of teachers comprised from both visiting experts in science and art (from the CREATIONS project) and several dedicated teachers from the school. During preliminary meetings with the school's staff, the CREATIONS trainers (from both art and science domains) support a decision about a specific scientific theme to realize with the pupils for their opera. This theme may be related to a current, past or future scientific topic, according to the interests of the school.

The demonstrator thus aims for *emotional* involvement on the part of the pupils within a *social* learning environment. A holistic approach to learning is created through the constant necessity of pupils' making connections and understanding common themes across disciplinary boundaries.

4.2 Student needs addressed

This demonstrator addresses the student need to rethink the boundaries of the science classroom. Those boundaries refer to both the physical infrastructure, and the people involved. The demonstrator vastly altered the physical setting of the classroom. In this demonstrator, the scientific theme of "supernova" was explored in the music room, outdoors, and the performance stage. It was explored with new "kinds" of educators. Thus, drama instructors, music instructors, and the complete community all became an integral part of the science classroom.

5. Learning Activities & Effective Learning Environments

The core group takes part in activities, simulating an "opera company" in which performers, composers, designers, scenographers, science educators, etc., collaborate to create an opera. There is therefore no "one size fits all" approach to the activity. Typically, a teacher will choose a scientific theme (in this case, astronomy), and engage the pupils in inquiry-based activities within both science and the arts.

Typically, for implementation in schools, the following may be required:

18. 2 classroom spaces (1 may be enough in some cases)
19. Musical instruments
20. Raw material for costumes
21. Stage (optional – may be performed without an official stage)
22. Audio equipment for performance
23. Access to scientific information (teacher/internet/book/research center)

The rest of the school follows this rotation[34] of stations by being divided into 4 groups (GR 1-4):

	Printing	**Choir and dance**	**Visual arts**	**Building / drama**
Day 1	Gr 1	Gr 2	Gr 3	Gr 4
Day 2	Gr 1	Gr 2	Gr 3	Gr 4
Day 3	Gr 4	Gr 1	Gr 2	Gr 3
Day 4	Gr 4	Gr 1	Gr 2	Gr 3
Day 5	Gr 3	Gr 4	Gr 1	Gr 2
Day 6	Gr 3	Gr 4	Gr 1	Gr 2
Day 7	Gr 2	Gr 3	Gr 4	Gr 1
Day 8	Gr 2	Gr 3	Gr 4	Gr 1

The following table outlines the learning activities and effective learning environments for the "core group" which creates and perform a school-opera at the end of the implementation:

[34] Rotation will take place on 8 of the 10 project days.

Science topic: Astronomy Class information Year Group: 4-7 Age range: 9-13 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate, e.g. pupils with language difficulties may contribute on an equal level to others by performing in the orchestra.	Materials and Resources *What do you need?* Various music instruments, materials for making costumes. Optional: Stage, lights *Where will the learning take place?* All activities will take place at the school, including visits from several science education professionals. *Health and Safety implications?* In the case of sewing costumes, it is important to ensure maximum safety by having a qualified teacher available at all times and corresponding instructions. *Technology?* Computer with internet (watching videos and searching for information). *Teacher support?* Team teaching with both arts and science and arts (music\dance\design\drama) expertise is recommended.

Prior pupil knowledge

No prior knowledge regarding astronomy is required for pupils. The idea of the demonstrator is to introduce specific topics chosen through a creative inquiry process of the pupils and in dialogue with their teachers, through the creation of the opera. No prior knowledge regarding the arts is needed for pupils. The method caters to all pupils, and includes exercises in e.g. music composition which allow novices to compose simple sections of the opera and take part successfully in all elements of the creative process.

Optional: music lessons including composition exercises; basic drama exercises; dance; arts & crafts classes; experience with school stage performances is an advantage

Assessment	**Differentiation**	**Key Concepts and Terminology**
The CREATIONS project (www.creations-project.eu) proposes		

guidelines for the assessment of pupils. These will be implemented before and after the school implementation. Criteria for the project's success are proposed by the Tjødnalio school team (see section on assessment, below).	*How can the activities be adapted to the needs of individual pupils?* The implementation is structured to include the whole school without exception (in excess of 200 pupils). However, pupils could volunteer to take the part in the "core group" which will create a full school-opera. All others must take part in "stations". Within the "core group" the creative process allows for pupils to apply for various roles in a (simulated) opera company. The methodology is able to adapt to each group of pupil's level in e.g. music or drama. It is the creative process of generating ideas as a group and implementing them which is at focus, rather than a level of virtuosity on e.g. a musical instrument.	**Science terminology:** Astronomy, Moon, Gravity, Solar System, Light. **Arts terminology:** 1) Aria: Solo song by one character. The plot's "action" is stopped to allow this character to express a certain emotion and inner feelings. 2) Duet: Two singers, preferably each singing their own verse followed by a section in which they sing together. 3) Ensembles: Three or more singers 4) Choir: The choir can be used to "comment" during the other songs, or as simple choir pieces. 5) Overture: Instrumental (no voices) opening piece which sets the mood of the opera. 6) Interlude: Music performed between acts or scenes. 7) Recitative: "Spoken Song" which tells a story, and which propels the plot further by revealing action (what has taken place, what will take place, a secret, etc.). 8) Tableau– A dramatic activity in which a group of pupils are asked to physically construct an opera scene through body placement, facial expressions, and props 9) Various musical instruments

Session Objectives:

During this scenario, students will inquire about curriculum-based astronomy; Experience musical, visual design, drama techniques as tools for the opera. Pupils will gain knowledge and experience with group-work in which various groups will create specific synopsis, libretto, composition, scenography, costumes for the opera, accompanied by a continued exploration of questions relating to astronomy. The libretto should include key concepts connected to the scientific theme. Scientific models and figures can be of great inspiration to scenography, costumes and music: Art and science intertwined. Throughout the scenario, pupils will learn to make their own decisions during inquiry processes, make their own connections between questions, planning and evaluating evidence, and reflect on outcomes.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Following initial astronomy experiments at the school, students (pupils) generate and write down words\ideas about Astronomy.	This session will be led by an inter-disciplinary team of science, music, drama and education professionals in cooperation with the teachers.	Experimenting with various musical instruments and drama techniques.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play*	Students compare their ideas to existing evidence provided through literature and	Guide students to relevant evidence.	Preliminary generation of story-ideas for

	is crucial in *empowering* pupils to generate, question and discuss evidence.	visiting and in-house science educators.		the opera's libretto.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse evidence and make conclusions regarding their own initiative.	Help students interpret the potential implications of the evidence for the students' own inquiry.	Begin creating and rehearsing the opera within the various arts disciplines (libretto, costumes, music, etc.)
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Formulations of scientific explanations.	Guide students in their consideration of possibilities.	Continued production of original material (music, etc.), and opera rehearsals.

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Formulating ideas in relation to discipline knowledge in a larger context, including how scientific and artistic ideas may cross-fertilize each other within the inquiry process.	Ensure scientific quality with regard to explanations	Continued rehearsals, costumes making.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate their knowledge and explore its ethical implications.	Supports the communication process and the opera performance logistics	Opera performance[35]: Inviting community (parents, other teachers, etc.). The "opera chief" (pupil) makes a welcome speech.

[35] See «Possible extension» below

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Reflection process regarding the scientific and artistic conclusions	Facilitates the reflection process.	Reflection on the process, and collection of documentation of data to the extent possible / sharing experiences via social media.

6. Additional Information

This demonstrator is based on the CREATIONS implementation at Tjødnalio School[36] in Stord municipality (Hordaland county, Norway). The school has a years-long tradition of "Culture Weeks" which engages the *complete school* in a wide variety of creative workshops, interventions and teaching approaches. The methodology is based on pupils rotating through various educational stations ("stasjonar") during the process. In 2017, Tjødnalio School is opening its doors to collaboration with the CREATIONS project to realize a 10-day long Astronomy-and-the-Arts exploration for the whole school. A **core group** of 40 pupils will take part in implementing a science opera approach, in cross-inspiration with the rest of the school which will participate in "stasjonar" inspired this year by the subject of Astronomy. In essence, the "core group" and its CREATIONS activity[37] becomes one of the "stations" in a much larger initiative. An added value is that the CREATIONs team will work with a group of 40 pupils, while the whole rest of the school (approx. 200 pupils) will also be involved in related activities which rely on the Tjødnalio school's practice of Culture Weeks. *Project leader: Assistant Professor (Drama) Kirsti Aksnes.*

<u>The History of "Culture Weeks" at Tjødnalio School</u>

When Tjødnalio school was established in 1991, it was decided upon a special goal for the school.
Jon Roar Bjørkvold had visited Stord and inspired the school's administration and politicians with a lecture inspired by the book «The Musical Human» (Norwegian: «Det musiske mennesket» (Bjørkvold, 1989). The school applied the following main goals inspired by Bjørkvold's work, implemented through project-based activities. It should be a school:

- Pupils and staff are satisfied and integrated
- Pupils and staff work creatively
- Pupils and staff prioritize musical values and create «complete», holistic humans
- Pupils are ensured the possibility of participation
- Which is communally active, and especially with regard to the cultural life and industry
- Which considers new working routines
- Which considers working across age boundaries

This can be achieved by following these concepts:

- Have an open school from morning to evening
- Inviting staff to think positively about new working methods, collaboration forms and routines
- Pupils, parents and staff are allowed to be active through their use of the schoo
- Accentuate and prioritize creative activities

These understanding led to the «Culture Weeks» tradition which lies as a foundation of this CREATIONs demonstrator.

[36] http://www.stord.kommune.no/tjodnalio-skule/

[37] https://www.youtube.com/watch?v=Rv-fwXbUFJo&feature=youtu.be

7. Assessment

The assessment is based on three main procedures: The CREATIONS project's assessment (pre and post implementation); the school's own assessment of the project with regard to whether or not it achieved the success criteria (see below), and the external educators' assessment of their own practice.

CREATIONS

CREATIONS implementations are assessed by both pupils and teachers. Evaluation analytics will show the effectiveness and efficiency of employing creative teaching approaches. The web analysis will be used to show a change in the users-behaviour. The evaluation approach of the CREATIONS project will use both qualitative and quantitative approaches. The umbrella question is: ***can the implementation of the*** **CREATIONS** ***features influence science motivation, or motivation for pursuing science respectively?***

Further details:

- Teachers fill out a short questionnaire (VALNET) regarding the impact of CREATIONS activities on the curricula. This will support the connection of CREATIONS with different schools and policy makers. In Norwegian, the link to this questionnaire is:
- Pupils fill out questionnaires pre- and post intervention (Science Motivation Questionnaire (SMQ). These are available in Norwegian and are sent to the school's head teacher for the pupils to fill.

Tjødnalio school

Tjødnalio set forth the following criteria for the success of the project, all of which were realized:

- Everyone participates
- Groups with mixed ages
- The creation of a project (opera) which can be shown to others
- Cultural evening with an invitation to all parents
- Inclusion of practical and aesthetic disciplines (mainly referring to arts disciplines and sports).

8. Possible Extension

The implementation will culminate with a large community event called "Kulturkveld" (Culture Evening) at the school. Several hundred visitors are expected to attend and see the CREATIONS performance on the evening of June 13th, 2017.

Examples of previous year's Culture Evening can be viewed following these links:

- Collection of pictures (2015): http://www.stord.kommune.no/Documents/Tjodnalio-skule/Kulturkveld/2015/Kulturkveldbilete.pdf
- Stord municipality web-announcement (Norwegian): http://www.stord.kommune.no/no/Tjodnalio-skule/Nyhende/Kulturkveld-i-os-pos-regn/

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

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CREATIONS project website (2015). www.creations-project.eu

CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.52 HYPATIA an online tool for visualization and discoveries using elementary particle collisions

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	S.Vourakis, C.Kourkoumelis
Code:	D 3.2.52.	**Contributors:**	
Version & Date:	**30/5/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

High Energy Physics at CERN

1.2 Type of Activity

Workshop with students: Introductory to elementary particles followed by hands-on activity with PC's. The students visualize the particle collisions, study their products and possibly make discoveries

1.3 Duration

2 and ½ hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

2. Rational of the Activity / Educational Approach

- Active participation in modern discoveries
- Development of analytical and critical skills
- Understanding of scientific concepts and phenomena
- Emulation of cutting edge research work using complex learning environments
- Involvement in high end scientific data analysis
- Develop skills of teamwork

2.1 Challenge

School curriculum focuses on the fundamental concepts of physics. That is undoubtedly necessary as a basis to understand more complex concepts. However focusing on discoveries made centuries ago and ignoring recent advances promotes an antiquated view of physics and fails to spark the students' interest towards it. It is necessary for them to learn how physics has evolved and what the current scientific view of the world around us is. This will not only give them a more complete view of what physics represents but also motivate them to take in interest in the physical sciences.

In this exercise, the students are offered high stimulating environments through which they get acquainted with the most advanced technological equipment. They are expected to understand quite complicated processes which take place when two very high energy particles collide to produce hundreds of fragments. They are also encouraged to collaborate with their teammate and among other teams to evaluate and explain their results.

2.2 Added Value

- Familiarize themselves with cutting edge technology required to build world's most complicated detectors
- Learn by interactive complex analysis in PCs
- Virtual visits to CERN and its experiments
- Live discussion with researchers at CERN
- Involvement in high end scientific data analysis
- Development of analytical thinking and critical skills
- Encouragement of decision independent making
- Understanding of scientific concepts and phenomena
- Develop skills of teamwork

3. Learning Objectives

School curriculum is usually limited to basic physics concepts that were discovered decades ago. While this is an important foundation for the understanding of modern physics, it also leaves the students with a very antiquated view of physics.

With this demonstrator we aim to present to the students a realistic view of how modern particle physics research is conducted at the most advanced particle accelerator in the world, the LHC, and its experiments. This will not only give students a detailed view of the advances in particle physics but also teach them about the structure of matter, the existence of a multitude of subatomic particles and their interactions. In addition it introduces them to the most advanced technological progress. It will also help them realize that working in experimental physics is something that they could do if they wish.

Furthermore, the exercise will help them develop analytical and teamwork skills that are required in most research environments even beyond physics.

3.1 Domain specific objectives

The students will learn about subatomic particles and their interactions, the structure of matter and the four fundamental forces in nature. They will also learn how modern particle physics research is conducted and new particles are discovered.

3.2 General skills objectives

Students will learn to apply their knowledge, analytical skills and reasoning to select the proper tracks from each event and combine them to "discover" new particles. They will also learn about teamwork and collaboration in comparing their results and discussing their differences.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics principles on their own. They have to gather their own results and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

4.2 Student needs addressed

The students involved in this exercise should have to have basic knowledge of physics and electromagnetism. Also a basic knowledge of the structure of the atom (or even elementary particles) is desired. Students work on pc's using the HYPATIA software which is intuitive and easy to use. Still basic computer skills are required. Finally the students have to prepare a report with their partners to show their results and understanding of the subject.

The HYPATIA demonstrator includes four different exercises with increasing level of difficulty. The lower one can be used by very young students to visualize the collisions of high energy protons and their products. The more complex involve 16 to 18 year old students.

5. Learning Activities & Effective Learning Environments

2 Question-eliciting activities

- Lecture about particle physics by experts
- Lecture about CERN and the LHC and detectors by experts
- Discussion/question/answer session with the students and teachers and experts

Active investigation

- Introduction to the HYPATIA software that will be used
- LHC interactive event analysis including possible discoveries of new particles
- Possible video Conference with other schools (for students)
- ➢ Active participation in the discovery of scientific concepts
- ➢ Development of analytical and critical skills
- ➢ Understanding of scientific concepts and phenomena
- ➢ Emulation of cutting edge research work
- ➢ Involvement in high end scientific data analysis
- ➢ Develop skills of teamwork

More Specifically:

- Students will learn the principles of basic science, concepts beyond the school curriculum
- Students will learn through playing games (at the entry level) and performing realistic high energy physics data analysis (at higher level)

Students will engage in hands-on activities which will allow them to understand and become familiar with the work of physicists working in the field of high energy. This will expose them to key concepts in modern physics and will help them develop an interest in it. They will learn about the building blocks of nature and their interactions.

Science topic: Particle physics. (Not part of most national curriculums) **Class information** **Year Group:** **Age range: 15-18** **Sex: both** **Pupil Ability: Basic computer usage required**	**Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection.** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **In a computer laboratory** ***Health and Safety implications?*** **None** ***Technology?*** ***Teacher support?*** **It is desired that the teacher would talk to the students during the previous days and introduce some of the concepts necessary for the exercise. This will make it easier for the students to absorb the multitude of information necessary to conduct the exercise.**
Prior pupil knowledge: Basic understanding of electromagnetism and atomic structure.	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **The aim of the lesson is twofold. First the students will understand important principles of high energy physics, subatomic particles and the structure of matter. Second they will learn how to work like actual researchers by evaluating and analyzing real data from the ATLAS experiment at CERN.** **As an additional outcome it can be combined with the art classes and the students to be asked to make their own visualization of the products of particle collisions and/or produce short artist videos which explain their findings.**	

Assessment	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** Subatomic particles, structure of matter, fundamental forces, particle decay **Science terminology:** -see above- **Arts terminology:** Particle collision visualization, Photographs, video, paintings

Session Objectives:
During this demonstrator, students will analyze data from the ATLAS experiment at CERN. They will perform the same tasks as actual researchers and will "discover" the Higgs boson. After the end of their analysis they will compare their results with those of other groups to confirm them and discuss possible differences, something that is also a basic part of physics research.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and	The main idea of this introduction is to get students to learn interactively about the cutting edge research done at the European Center of Particle Physics (CERN) located in Geneva across the	Teachers should make a brief introduction to their students about CERN and basic research and engage them in watching videos about CERN in general and about the ATLAS detector which	

	personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	French-Swiss border. At the same time they will become familiar with the new technologies developed in order to construct and operate the giant accelerator and the experiments installed in it. Engage with teacher's questions. Watch videos and use the web to gather more information.	they will use for identifying particles in phase 3. The goal is to give students a basic idea about the research being conducted at CERN but also learn about some of the fundamental physics principles that are necessary to understand before proceeding with data analysis.	
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students will briefly learn about the operation of the LHC accelerator, the discoveries it made about the elementary particles and how they can be classified in families. Students need to understand that	The teacher, after an introduction to the particle world, should try to talk to the students about the Higgs boson. He/she should explain its role in particle physics and its significance in shaping the world around	

		modern physics has moved far beyond the structure of the atom than they learn at school. In order to conduct the exercise they need to become familiar with the characteristics and properties of some of the subatomic particles that have been discovered in recent decades as well as the signatures they leave in the ATLAS detector.	us. This will highlight the importance of its discovery four years ago.	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	This is the main part of the demonstrator. Students using the HYPATIA tool (hypatia.iasa.gr) look at a number of real events that were detected by the ATLAS experiment at CERN. They have to	The teachers should closely monitor and guide the students to the use of the tool, the understanding of track characteristics and the combination of tracks. The tool is complex and about a teacher for	

		determine based on the information they have been given in the previous phases and the information that is presented by the event display application whether a specific track represents an electron or a muon which originated from a Z or Higgs boson decay. Furthermore they should combine two or four electrons/muons to reconstruct the mass of the Z boson and finally discover the Higgs particle!	every group of 6-8 students is needed.	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The student should summarize their results here. They should discuss within their teams which of their results are acceptable	The teacher should help students interpret the histograms, discuss errors and deviations. It is important for the students to understand	

		and which should be removed. They should look at the differences (if any) between the electron and muon results they have gathered and attempt to explain them.	the difference between an experimental error and a wrong measurement. They should explain that evaluating and assessing experimental errors is a vital part of experimental physics and that students should not expect perfect results when conducting real experiments.	
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students should compare their results with already known measurements in literature (if they exist). Deviations from the known values should be discussed.	Teachers should help students search in the literature and critically compare results (eg. if taken under the same conditions etc). It is important for the teacher to emphasize that in many cases (such as the Higgs discovery) when the	

			theories can't provide the exact properties of the particles it is through this detailed and accurate experimental process that those properties are determined.	
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students compare their results with other students and discuss the results and the differences they may contain. They can also make short presentations of their results while they explain any deviation from the expected measurements (electron/muon asymmetries, mass or width deviations etc).	The teachers should make sure that enough time for discussion and communication is given to each group of participating students. They should also emphasize that comparing and discussing results of different groups is the actual process that leads to discoveries. Results that can't be independently verified and methodologies that are not precisely determined	

			are not accepted in the scientific world.	
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Time to look back at what they have learned. Students can compare their views of particle physics and subatomic particles before and after the exercise.	This should be guided by the teachers. They can emphasize the importance of understanding the processes that govern the world around us and how this has transformed our lives.	

6. Additional Information

- http://hypatia.iasa.gr/
- http://hypatia.phys.uoa.gr/

7. Assessment

There are assessment questions embedded in the ISE HYPATIA demonstrator. The students' answers can be collected and provde information about the length of the student's understanding and length of involvement in each phase.

8. Possible Extension

There are several scenarios which can be used as extensions for the demonstrator

A) Calculating masses of parent particles decaying to 2 or 4 daughter ones. HYPATIA has the capability of calculating the invariant mass of particles decaying to one or two pairs of particles. This can be used to extend the exercise beyond the discovery of the Z and Higgs bosons.

B) Measuring the magnetic field of the ATLAS detector. The magnetic field of the central solenoid of the ATLAS detector bends particle tracks as they move through it. The curvature of the tracks can be used through HYPATIA to measure the intensity of the magnetic field.

C) Optimizing the criteria for background suppression in batch even analysis. HYPATIA can perform batch analysis on thousands of events. In this mode two collections of events are selected (signal and background) and a set of parameters determining which events are selected is optimized by the user through the use of a series of graphs for each of them. The goal of the exercise is to select the optimal set of parameters that will remove as much of the background as possible while leaving the signal relatively intact.

9. References

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- Dimitris Fassouliotis, Christine Kourkoumelis, and Stylianos Vourakis The Inspiring Science Education project and the resources for HEP analysis by university students ICNFP 2015
- http://portal.opendiscoveryspace.eu/edu-object/hypatia-demonstrator-english-v2-828289

D3.2.53 Let's Accelerate Particles: learn about the LHC accelerator by playing a game

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	C.Kourkoumelis, G.Vasileiadis
Code:	D 3.2.53	**Contributors:**	
Version & Date:	**30/5/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Motion of particles in electric and magnetic fields, acceleration of particles, High Energy Physics at CERN

1.2 Type of Activity

Workshop with students: Introduction to elementary particles followed by hands-on activity with PCs. The students follow interactively all stages of acceleration of particles by playing an educational game

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

- Introduction to High Energy Physics
- Understanding of scientific concepts and phenomena
- Active participation in modern physics research
- Emulation of cutting edge research work using playful learning environments
- Develop skills of teamwork

2.1 Challenge

School curriculum focuses on the fundamental concepts of physics. That is undoubtedly necessary as a basis to understand more complex concepts. However, focusing on discoveries made centuries ago and ignoring recent advances promotes an antiquated view of physics and fails to spark the students' interest towards it. It is necessary for them to learn how physics has evolved and what the current scientific view of the world around us is. This will not only give them a more complete view of what physics represents but also motivate them to take an interest in the physical sciences.

In this exercise, the students use an attractive learning environment which helps them to get acquainted with the most advanced technological equipment. They are expected to understand quite complicated processes which take place in order to operate the world's most powerful accelerator. They are also encouraged to collaborate with their teammate and answer knowledge and assessment questions.

2.2 Added Value

- Learn about the motion of charged particles in electromagnetic fields
- Understanding of scientific concepts and phenomena
- Familiarize themselves with cutting edge technology required to build world's most complicated accelerators
- Virtual visits to CERN and its experiments
- Live discussion with researchers at CERN
- Develop skills of teamwork

3. Learning Objectives

School curriculum is usually limited to basic physics concepts that were discovered decades ago. While this is an important foundation for the understanding of modern physics, it also leaves the students with a very antiquated view of physics.

With this demonstrator we aim to present to the students a realistic view of how modern particle physics research is conducted at the most advanced particle accelerator in the world, the LHC, and its experiments. This will not only give students a detailed view of the advances in particle physics but will also teach them about the structure of matter, the existence of a multitude of subatomic particles and their interactions. In addition it introduces them to the most advanced technological progress and helps them understand the challenges and difficulties presented when particles are accelerated at unprecedented energies.

3.1 Domain specific objectives

The students will learn about subatomic particles and their interactions, the structure of matter and the four fundamental forces in nature. They will also learn how particles move in electric and magnetic fields and how large numbers of particles are focused together to produce pencilike beams. Finally they will visualize the products of collisions of such beams of particles.

3.2 General skills objectives

Students will learn to apply their knowledge of electric and magnetic forces in practice in order to achieve their ultimate goal guided along all steps by the professional LHC engineers.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics applications on their own. They have to gather the answers to the knowledge questions (the correct answers are provided afterwards) and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

4.2 Student needs addressed

The students involved in this exercise should have basic knowledge of physics and electromagnetism. Also a basic knowledge of the structure of the atom (or even elementary particles) is desired. Students work on PCs using the LHC game (played using the Flash software) which is intuitive and easy to use. It is part of the software developed by CERN within the CERNland applications which include a number of other games for younger ages.

Students of ages 12-15 will enjoy playing the game.

5. Learning Activities & Effective Learning Environments

3 Question-eliciting activities

- Lecture about particle physics and accelerators as giant microscopes by experts
- Lecture about CERN and the LHC and accelerating techniques by experts
- Discussion/question/answer session with the students and teachers and experts from CERN

4 **Active investigation**

- Introduction to the different stages of the LHC game software that will be used
- LHC interactive game
- Possible video Conference with other schools (for students)
- Understanding of scientific concepts and phenomena
- Emulation of cutting edge research work
- Involvement in high end scientific research
- Develop skills of teamwork

More Specifically:

- Students will learn the principles of basic science, concepts beyond the school curriculum
- Students will learn through playing games.
- Students will engage in hands-on activities which will allow them to understand and become familiar with the work of physicists working in the field of high energy physics. They will learn about probing matter deeper and deeper using accelerators and different particle beams. They will also learn about the use of accelerators in everyday life (hospitals, sterilization etc).

Science topic: Electricity and Magnetism and Particle physics. (Not part of most national curriculums) **Class information** **Year Group:** **Age range: 12-15** **Sex: both** **Pupil Ability: Basic computer usage required**	**Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection.** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **In a laboratory equipped with PCs** ***Health and Safety implications?*** **None** ***Technology? PCs with Flash Player installed, A projector*** ***Teacher support?*** **It is desired that the teacher talks to the students before the activity takes place. This will make it easier for the students to absorb better the impact of the game.**
Prior pupil knowledge: Basic understanding of electromagnetism, the basic forces and atomic structure.	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **The aim of the lesson is twofold. First the students will understand important principles of the structure of matter. Second they will learn that scientists at CERN try to further probe matter in subatomic dimensions and they will become familiar with the technological advances that help us uncover the mysteries of nature.** **As an additional outcome it can be combined with the art classes and the students to be asked to make their own visualization of the products of particle collisions and/or produce short artist videos which explain their findings.**	

Assessment	Differentiation	Key Concepts and Terminology
Collect answer to knowledge and assessment questions	*How can the activities be adapted to the needs of individual pupils?* *By adjusting the duration of time spent in each phase and the discussion in between.*	Subatomic particles, structure of matter, fundamental forces, electric and magnetic fields, interaction of particles with electromagnetic fields, particle accelerators, dipole and quadrupole magnets **Science terminology:** -see above- **Arts terminology:** Particle collision visualization, Photographs, video, paintings

Session Objectives:

At the end of the session they should have completed successfully all the steps needed to accelerate and collide particles at the LHC. They should have answered correctly the knowledge and assessment questions. Finally they should have discussed with their teachers the applications of accelerators in everyday life.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of	The purpose of this introductory phase is to provoke the curiosity of the students by making them aware of the cutting edge research done at the European	Teachers should make a brief introduction to their students about the elementary particles, CERN, general concepts of basic research in High Energy Physics	

	professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	Center of Particle Physics (CERN). The principle idea is to point out the importance of this research as well as the difficulties humanity faces when studying nature. As soon as the goals of the scientists are understood, the question of "how is that made possible?" is the next natural step. They will, therefore, become familiar with the new technologies developed in order to construct and operate the giant accelerator and the experiments installed in it. To do so, they will try to answer general purpose teacher's questions, watch videos and use the web to	and engage them in watching videos about CERN and the LHC accelerator, since the main part of this activity focuses on understanding the principles behind the operation of particle accelerators and their applications in everyday life.	

		gather more information.		
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	This Phase follows the general purpose introductory Phase 1. The aim of this Phase is to give students a broader understanding of the difficulties involved in achieving particle acceleration at High Energies. To do so, the interaction of particles with electromagnetic fields is presented in this phase. The behavior of different particles is studied based on scientific evidence. The process of accelerating particles is divided in three logical steps based on the behavior	The teacher has a lot of freedom when explaining the various concepts of this phase. He/she is expected to choose a procedure that best suits his/her school curriculum as well as the current level of the class. A general recommended approach when teaching these concepts is to present only the basic physical principles that govern the interaction of particles with each other as well as with fields, and then pose questions to the students that aim at extracting from them the	

		of particles in electromagnetic fields as well as the interactions between particles: 1) accelerating particles, 2) bending particles and 3) focusing particles.	optimal way to accelerate particles based on their physical properties and the constraints that stem from them. Naturally, the activity it self will provide the relevant guidance in order to achieve this goal.	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	This is the most interactive part of the demonstrator and the most important one since students will be asked to play a relatively easy game that requires implementation of the knowledge they gathered in the previous phases. The ultimate goal of the game is to accelerate particles in the LHC following the exact	Teachers are expected to have tried the game beforehand in order to guide the students through the various steps if needed. The teacher role in this part of the exercise is minimal. They should provide feedback to the students that need it and clarify any notions that haven't been understood. The use of the game provides a natural framework that	

		steps that scientists at CERN follow when accelerating beams of protons. The game is simple and well documented. The aim is to give practical meaning to the words "accelerating, bending and focusing particles" by actively engaging the students in this procedure.	the teacher can use in order to help him/her communicate and analyze the scientific concepts involved.	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The goal of this Phase is to make sure the students have mastered the relevant material. Some of the students will have understood the concepts exposed in this activity, whereas others might still have questions whether they choose to come forward with them or not. In	The role of the teacher in this part of the exercise is vital. The teacher should try to guide the students by asking questions relevant to the problems and seeking solutions to these problems. He/she should promote teamwork in solving	

		this phase they are expected to be able to explain what happens when we try to accelerate particles, how and why it happens. Ultimately, they should work in groups of two (or more) in order to provide suggestions for future particle accelerators.	these problems. The utmost importance of the role of the teacher stems from the fact that he/she should try to understand what concepts of the activity were not understood from the students, and guide them in understanding these concepts by asking the appropriate questions.	
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Phase 5 assumes that a thorough discussion took place in Phase 4, since now the students will be asked to compare the solutions that they proposed with the solutions that the scientific community has chosen for future accelerators. There are	The activity itself provides the necessary guidance a teacher may need in order to actively engage the students in this discussion. This is the Phase that the teacher is able to showcase some of the most fascinating ideas of Science and provoke the curiosity of the	

		many physical concepts and restrictions that can be discussed in this Phase (the speed of light, particle radiation, etc).	students for concepts that go beyond the scope of this activity. Phases 4 up to 7 can be extended as much as needed based on the interests of the teacher and the students.	
Phase 6: COMMUNICATE : students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students compare their results with other students and discuss the results, the different approaches and the possible outcome of the various suggestions. Depending on the school infrastructure and the personnel availability, a remote connection with CERN can be established in this phase so that the students can expose their ideas to a scientist	The teacher is the coordinator of this procedure and holds a secondary role as the main goal is to provoke student communication and exchange of ideas on a scientific background. At the end of this phase the teacher should highlight the fact that this is a model of the actual procedure followed by scientists when doing research.	

		actively engaged with this research and ask questions or further guidance.		
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The goal of this phase is to sum up the outcomes of the activity. The students could participate in non-competitive questionnaires in order to determine the amount of teamwork and the results produced from each group (scientifically valid suggestions, feasible future experiments, etc).	The goal of the teacher is to sum up the goals of the activity, the new concepts, the achieved results and the possible future applications of what the students learned during the exercise. He/she should also highlight once more the applicability of accelerators in modern life and the high expectations for future technological break-throughs based on particle accelerators.	

6. Additional Information

- The game exists in different languages: French, English, German and Italian

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

There are assessment questions embedded in the ISE LHC game demonstrator. The students' answers can be collected and provide information about the length of the student's understanding and length of involvement in each phase.

8. Possible Extension

There are several other games with the general framework of the CERNlab shttp://www.cernland.net/index.php?.

The Microboy game can also teach in a playful way the chemical composition of atoms.

A natural extension of this Demonstrator –but for older kids- is the HYPATIA demonstrator that studies the collisions of particles after they are accelerated to the desired energy.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

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D3.2.54 The structure of the Atom

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**V.Papadimitrakopoulos,** C.Kourkoumelis, S.Vourakis
Code:	D 3.2.54.	**Contributors:**	
Version & Date: 15/9/2017		**Approved by: NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics. The structure of the atom, the fundamental particles and how they are combined to make up matter. The significance of subatomic physics in science and in everyday life.

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).

Workshop with the students: Introduction to the nucleons and the quarks followed by multimedia with PC's. The students are shown interactively the structure of the atom.

1.3 Duration

1 and ½ hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Art based activities aiming to increase the students' creativity and heighten their comprehension and interest on the subject. (possible cooperation with the art teacher, namely the students divide into teams and present art projects like plays, handicrafts, drawings)

2. Rational of the Activity / Educational Approach

2.1 Challenge

Primary school's curriculum is limited to basic concepts of physics which sometimes proves to be unattractive for the students. Physics is often considered boring and hard to understand due to the curriculum and the way that physics is taught.

This activity's challenge is to introduce the students to the atomic and subatomic physics in the limited duration of a school hour which will be followed by art activities. They are about to get acquainted with the fundamental particles and their combinations which make up everything. This exercise is an attractive learning environment given in a playful way which will help them understand the structure of the matter, spark their interest in physics and be better prepared for the secondary school's physics.

2.2 Added Value

- Development of analytical thinking and critical skills
- Understanding of basic scientific concepts and phenomena
- Development of teamwork skills
- Familiarization with fundamental particles, atomic and elementary particle physics
- Familiarization with the research being done at CERN
- Learning about the applications of subatomic physics
- Art based activities will also give the opportunities for the students to participate, take action, to learn, create and improve their conceptual understanding

The added value of using the specific proposed approach (Demonstrator) during the educational process is that it successfully introduces the scientific methodology in school science education, by utilizing existing research infrastructures of frontier research institutions enriched and expanded with creative approaches to develop artworks. The students' benefits from the combination of Art and Science is that they have the opportunity to learn, create and self-create as active and connected players in their emotionally rich, virtual and actual play-opportunities to engage in possibility thinking, making the transition from what is to what might be; opportunities to participate, take action, have their voice heard.

3. Learning Objectives

3.1 Domain specific objectives

- Attract students' interest with modern and interactive means
- Get students interested in science and research through art activities
- Development of analytical and critical skills
- Active participation in modern physics research
- Understanding of scientific concepts and phenomena
- Development of teamwork skills
- Eventual understanding of how fundamental particles are built and combined to make up matter
- Open the school to the community
- Engage parents and the general public into schools' happenings and events
- Build National-wide student networks

The students will learn about molecules, atoms, nuclei, nucleons, the structure of the nucleons, the quarks and elementary particles.

They will also be encouraged to collaborate with their teammate and answer knowledge and assessment questions as well use their artistic insight to picture the atoms and molecules.

3.2 General skill objectives

Students will learn to apply their knowledge, collaborate to solve problems and visualize the atomic world. They also learn to perform confidentially following orders, adapt, form and follow a system of values and perform creatively through the projects.

- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art
- Develop spirit of cooperation and teamwork
- Connect the science classroom with professionals, parents and local communities

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics applications on their own. They have to gather the answer to the knowledge questions and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

The demonstrator aims at the enhancement of the students' cognitive involvement, their representation of scientific content using their cognitive processes, the students' sensorimotor involvement using their bodies or gestures, their emotional involvement, the social interaction and communication between them, the use of past experiences and the creation of new ones based on beliefs and behaviors, their brain, body and emotion coordination and finally the holistic use of their personality and their motives.

4.2 Student needs addressed

The students after this activity will better understand the structure of matter and what simple atoms and molecules are made of by putting together their constituents. Through this project they will meet a modern and interesting image of physics in a playful and easy way. This will motivate them to take an interest in the physical sciences. Also by constructing 3D models of atoms and molecules they will better understand the interconnection of the microcosmos and art.

5. Learning Activities & Effective Learning Environments

Science topic: Atomic physics/structure of atoms and matter (Relevance to national curriculum) Class information Year Group: Age range: 8-11 Sex: both Pupil Ability:: Basic computer usage required	Materials and Resources *What do you need? (eg.* printed questionnaires, teleconference, etc.) A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection. A teleconference to follow a possible Virtual Visit to a CERN experiment. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc.), or one?* In a laboratory equipped with PC's *Health and Safety implications? None* *Technology?* The computers and the projector *Teacher support?* It is desired that the teacher would talk to the students before the event takes place. This will make it easier for the students to better absorb the impact of the game.
Prior pupil knowledge Knowledge of the basic model of the atom desired	

Individual session project objectives During this scenario, students will pass through seven stages where they will approach scientifically the subject of the demonstrator. They will gather information, analyze, discuss, make conclusions. In each phase, they will be asked to perform creatively and present an art project. Eventually, they will be asked to make a small exposition to their parents and the public in the form of a science fair.		
Assessment Teacher's Questionnaires	**Differentiation** The students work in groups of two and collaborate with the other teams	**Key Concepts and Terminology** Fundamental forces, Elementary particles, structure of matter, High energy physics **Science terminology:** See above **Arts terminology:** Visualization of motion, Photographs, video, paintings, a play with students acting as particles

Session Objectives: During this scenario, students will learn about the structure of the atom and how atoms are combined to make up matter. In addition, they will learn about the applications of subatomic physics so they can realize the importance of studying the microcosm.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	The main idea of this introduction is to get students to learn interactively about the structure of the atom, protons and neutrons tied together in the nucleus and electrons orbiting around the nucleus.	Teachers should briefly introduce the students to the structure of the atom. They can use challenging questions and the web (images, videos) to	Possible initial collaboration with arts teachers to visualize the structure of an atom. The students can

		Engage with teacher's questions. Watch videos and use the web to gather more information.	attract the students' interest. He/she will also try to talk about the structure of the protons, neutrons and electrons and then give them a simplified view of the general structure of the atom. Therefore, the students will get familiarized with the fundamental physics which is necessary to	build 3D models of atoms as shown in this link: **3D atom models**

			understand before proceeding with the next phases.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students will briefly learn about how atoms are held together by chemical bonds and form molecules. In addition, they will learn about the different types of chemical bonds.	The teacher should talk to the students and encourage them to search and understand the importance of studying the structure the molecules which form everything around us, including ourselves. The use of questions, tasks and multimedia is	Possible collaboration with arts teachers to visualize the chemical bonds. The art project is: Present a chemical bond. Each team can make an acting, a drawing, a video or do

			recommended. This phase will attract students' interest and highlight the significance of the subatomic world.	handicraft to present atoms held together with a chemical bond.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	This is the main part of the demonstrator. The students give priority to evidence. As they have learned how the atoms are formed, they will use CernLand website where they can built atoms through interactive games.	The teachers should closely monitor and guide the students to the use of the tools.	Collaborate with art teacher so they can build 3D molecule models as they did with atoms. They can use the atom of carbon and build different molecules.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analyzed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The students are given a comprehension question. They can work in teams and use argumentation to formulate answers and explanations.	The teacher should help students understand how important is for them to play with ideas and analyze evidence to come up with any explanation or answer.	Each team can use digital modes (internet, make a video, draw) to present its answer to the other teams.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students are called to connect what they have learned to scientific knowledge such as the role of the structure of the atom and the combination of fundamental	Teachers should discuss and show students the applications of studying subatomic	Each team can make a clue -a drawing or a video or an acting- for each 3D molecule model that

		particles in forming different elements of nature. They will also get familiarized with the applications of subatomic physics in everyday life and science.	physics in science, technology, industry, medicine.	they have made in phase 3. Then the other team will have to match the clues with the 3D molecule models. This will help them visualize how atoms are combined to build molecules that form matter.

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students compare their results with other students and discuss the results and the differences they may contain. They can also make short presentations of their results.	The teachers should make sure that enough time for discussion and communication is given to each group of participating students. They should also emphasize that comparing and discussing results of different groups is the actual process that leads to discoveries.	Continue visualization using digital modes as well in their presentations (photos, films)

			Results that can't be independently verified and methodologies that are not precisely determined are not accepted in the scientific world.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Time to look back at what they have learned. Students can compare their views discuss and their impressions.	This should be guided by the teachers. They can emphasize the importance of understanding	The teachers along with the students select few examples of their creations in order to make a small exposition to

			of studying the microcosm.	their parents and the public in the form of a science fair.

6. Additional Information

A lot of information in the form of illustrated lectures/lessons can be found in the "Particle Adventure" http://www.particleadventure.org/

7. Assessment

The students' answers from the last phases of the demonstrator can be collected in a written form and provide information about the length of the student's understanding and length of involvement in each phase.

In addition, the teacher can use Questionnaires in order to estimate the student's comprehension and gain of knowledge. The answers of questions should be discussed with the students after the assessment.

8. Possible Extension

The teachers and students could run an educational scenario which is called "All that matters" http://tools.inspiringscience.eu/delivery/view/index.html?id=02afe7b3264f4848bf59c42a6b07e3cf&t=p .This includes the TOTEM game which teaches them how the nucleons are made.

9. References

A video picturing particles

https://www.youtube.com/watch?v=259asTAjts0

Some videos about CERN

https://www.youtube.com/watch?v=PHP13tTjidA

https://www.youtube.com/watch?v=sL3PK0kmD98

CERN's microcosmos exhibition

https://www.youtube.com/watch?v=ZB0vnP7uuko

D3.2.55 The Magnetic Field and its applications

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**V. Papadimitrakopoulos, C.Kourkoumelis, S.Vourakis**
Code:	D 3.2.55	**Contributors:**	
Version & Date: 11/9/2017		**Approved by:**	NKUA

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics. The Lorentz Force, the motion of particles in the magnetic field, application of the magnetic field in everyday life and science, the accelerators based on the circular motion of particles.

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).

Workshop with the students: Introduction to the magnetic field and the Lorentz Force followed by multimedia with PC's. The students are shown interactively the motion of particles in the magnetic field

1.3 Duration

1 and ½ hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Art based activities aiming to enhance the students' creativity and increase their comprehension and interest on the subject. (possible cooperation with the art teacher, namely the students divide into teams and present art projects like plays, handicrafts, drawings)

2. Rational of the Activity / Educational Approach

2.1 Challenge

School curriculum focuses on the fundamental concepts of physics. That is undoubtedly necessary as a basis to understand more complex concepts. However focusing on discoveries made centuries ago and ignoring recent advances promotes an antiquated view of physics and fails to spark the students' interest towards it. It is necessary for them to learn how physics has evolved and what the current scientific view of the world around us is. This will not only give them a more complete view of what physics represents but also motivate them to take an interest in the physical sciences.

In addition, due to recent Greek curriculum changes, the theory of magnetism has been removed from the curriculum. The teachers always complain about this lack of knowledge which is a serious obstacle to our efforts to unveil to the students the world of particle physics. The students do not understand how accelerators work or why particle detectors include huge magnets. Moreover they do not understand how the magnetic tomography or high speed trains work. This demonstrator aims to present to the students a realistic description of the magnetic field and its impact in modern science and everyday life. This will not only give students a detailed perspective of its applications but also introduce them to how the field influences the motion of charged paarticles. In addition it introduces them to some of the most advanced technological progress and helps them understand the challenges and difficulties presented when particles are accelerated at unprecedented energies.

2.2 Added Value

- Learn about the motion of particles in magnetic fields
- Understand how magnetic fields are used by giant particle detectors to bend particle tracks and measure their momentum
- Understand how magnetic fields are used by CERN accelerators
- Familiarize themselves with the applications of magnetic field in navigation, medical physics.
- Understand scientific concepts and phenomena
- Develop analytical thinking and critical skills
- Develop skills of teamwork
- Art based activities will also give students the opportunity to participate, take action, learn, create and improve their conceptual understanding

The added value of using the specific proposed approach (Demonstrator) during the educational process is that it successfully introduces the scientific methodology in school science education. It creates a pool of activities that provide access to CERN infrastructures (LHC, ATLAS) and promotes creative problem solving, discovery, learning by doing, experiential learning, critical thinking and creativity, simulating real scientific work by utilizing existing research infrastructures of frontier research institutions enriched and expanded with creative approaches to develop artwork. The students' benefits from the combination of Art and Science is that they have the opportunities to learn, create and self-create as active and connected players in their emotionally rich, virtual and actual play- opportunities to engage in possibility thinking, making the transition from what is to what might be; opportunities to participate, take action, have their voice heard. The students' comprehension and interest on the subject heightens.

3. Learning Objectives

3.1 Domain specific objectives

- Attract students' interest with modern and interactive means
- Get students interested in science and research through art activities
- Development of analytical and critical skills
- Active participation in modern physics research
- Understanding of scientific concepts and phenomena
- Development of teamwork skills
- Eventual understanding of how magnetic forces are used to accelerate particles in CERN
- Open the school to the community
- Engage parents and the general public into schools' happenings and events
- Build Nation-wide student networks

The students will learn about magnetic field lines, polarity, attraction and repulsion, Lorentz force. They will also learn how particles move in magnetic fields. Finally they will visualize how the giant ATLAS detector uses magnetic fields to bend the tracks of particles produced in high-energy collisions.

3.2 General skills objectives

Students will learn to apply their knowledge of magnetic forces in practice in order to visualize the effect of low and high magnetic fields on charged particles. They will also learn to form and follow a system of values, think critically, adapt, collaborate, create, perform independently and precisely through the projects.

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Scientific interconnection of science with aspects of art
- Develop spirit of cooperation and teamwork
- Connect the science classroom with professionals, parents and local communities

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics applications on their own. They have to discover the answer to the knowledge questions and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

The demonstrator aims at the enhancement of the students' cognitive involvement, their representation of scientific content using their cognitive processes, the students' sensorimotor involvement using their bodies or gestures, their emotional involvement, the social interaction and communication between them, the use of past experiences and the creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors, their brain, body and emotion coordination and finally the holistic use of their personality and their motives.

4.2 Student needs addressed

The students will get familiar with the magnetic field, the forces applied to charges or currents. This will give them a more complete view of how electromagnetism is used in everyday life, will fill the gap that curriculum created and will also motivate them to take an interest in the physical sciences. In addition it introduces them to the most advanced technological progresses like the use of magnets to build very high energy accelerators or superconductive magnets.

5. Learning Activities & Effective Learning Environments

Science topic: Magnetism, magnets and accelerators (Not part of the Greek national curriculum) Class information Year Group: Age range: 12-17 Sex: both Pupil Ability: Basic computer usage required	Materials and Resources *What do you need? (eg.* printed questionnaires, teleconference, etc.) A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection. A teleconference to follow a possible Virtual Visit to a CERN experiment. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* In a laboratory equipped with PC's *Health and Safety implications?* None *Technology?* The computers and the projector *Teacher support?* It is desired that the teacher would talk to the students before the event takes place. This will make it easier for the students to better absorb the impact of the game.
Prior pupil knowledge: Basic understanding of vector fields, velocities, fields.	

Individual session project objectives During this scenario, students will pass through seven stages where they will scientifically approach the subject of the demonstrator. They will gather information, analyze, dialogue, make conclusions. In each phase, they will be asked to perform creatively and present an art project. Eventually, they will be asked to make a small exposition to their parents and the public in the form of a science fair.		
Assessment Teacher's Questionnaires Student's Questionnaires	**Differentiation** The students work in groups of two and collaborate with the other teams	**Key Concepts and Terminology** Fundamental forces, Magnet fields, charged particles, High energy physics **Science terminology:** -see above- **Arts terminology:** Visualization of motion, Photographs, video, paintings, a play with students acting as particles
Session Objectives: During this scenario, students will learn and understand the magnetic field's properties and how scientists use it in experimental physics. In addition they will learn about the magnetic field's applications in everyday life, so they can realize its importance.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	The main idea of this introduction is to get students to learn interactively about the notion of the magnetic field, permanent magnets and electromagnets, Earth's magnetic field and the main types of magnets: solenoid, toroid, dipoles etc. Engage with teacher's questions. Watch videos (iron filings, superconductors, magnetic levitation, earth's magnetic field) and use the web to gather more information.	The teacher should briefly introduce the students to the magnetic field. Initially, he/she will try to talk about magnetic field lines, polarity, attraction and repulsion and subsequently about the Lorentz force and its impact in the motion of a particle or a body in a magnetic field. Therefore, the students can get familiarized with the fundamental physics and principles of the magnetic field, Lorentz force equation and right hand	Possible initial collaboration with arts teachers to visualize magnetic field lines and right hand rule. The students may draw the magnetic field lines of a magnet (could be the Earth!) with various colors and make a big painting.

			rule, which are necessary to understand before proceeding with data analysis.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	The students will briefly learn about Earth's magnetic field and how it protects life from solar wind. The modern use and applications in experimental science in CERN (colliders, detectors, accelerators), in navigation (compass), in medical physics (tomography).	The teacher should talk to the students and encourage them to search and understand magnetic field's impact and its applications in everyday life and experimental science. The use of questions, tasks and multimedia is recommended. This phase will attract students' interest and highlight magnetic field's importance.	Possible collaboration with arts teachers to visualize and create an art project about how to make a compass themselves. A helpful link **create a compass** **create a compass 2**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	This is the main part of the demonstrator. The students give priority to evidence. They are given equations which determine circular motion and shown video about	The teachers should closely monitor and guide the students to the	Collaborate with arts teachers to draw the results of high energy particle collisions.

		circular path of plasma, video about the circular motion of LHC beam. They are asked to do a back of the envelop calculation of what B is needed to make particles around the LHC and compare it with Earth's B. Then they are introduced to an interactive platform where they can change the charge, velocity and direction of various kinds of particles as well as the strength of the magnetic field and watch/record the action on fields on them. As an example they record the track radius as a function of momenta.	use of the tools and calculations.	The students could also create a short video where they could show how particles bend in the giant ATLAS detector.
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The student should summarize their results here. They should discuss within their teams the results of the experimentation of the previous phase and compare their data. They should look at the differences between the orbits and the velocities	The teacher should help students understand how magnetic field affects the motion of charged particles. She/he should also talk to them about field lines and subsequently about the	Visualize in artistic way data collection and display of results. They can draw the different orbits of the different particles in a single drawing so they can compare them.

		of the different particles moving in different strengths and orientation of magnetic field and try to formulate an explanation based on evidence.	absence of magnetic monopoles.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students should compare their results with already performed calculations based on the formulas given. Deviations from the known values should be discussed. Then they are called to connect explanations to scientific knowledge and applications of magnetic field.	The teacher should discuss and show students magnetic field applications in science (different types of accelerators, superconducting magnets), technology (magnet train), industry, navigation, medicine (tomography).	Collaboration with arts teacher. Art project Visualization of a –magnetic field- accelerator. The students can divide into teams and try to find original ideas. (drawing, acting- each student can have the role of a particle, even the magnetic field itself can be represented by an actor who bends the orbit of the other actors-particles- , make a video, handicraft, visualization with 3D models etc)

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students compare their results with other students and discuss the results and the differences they may contain. They can also make short presentations of their results	The teachers should make sure that enough time for discussion and communication is given to each group of participating students. They should also emphasize that comparing and discussing results of different groups is the actual process that leads to discoveries. Results that can't be independently verified and methodologies that are not precisely determined are not accepted in the scientific world. Emphasis should be given to medical applications of the magnetic field and the	Continue visualization using digital modes as well in their presentations (photos, films)

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			small hospital accelerators.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Time to look back at what they have learned. Students can compare their views discuss and impressions.	This should be guided by the teachers. They can emphasize the importance of understanding of the magnetic field's nature and impact.	The teachers along with the students select few examples in order to make a small exposition to their parents and the public in the form of a science fair.

6. Additional Information

A demonstrator of how the LHC accelerator works and how the dipole magnets bend the particles while the quadrupoles ones focus the particles is given in a CREATIONS scenario http://tools.inspiringscience.eu/delivery/view/index.html?id=c4e9fd501dce4f6290d35f8dcb9dcf1d&t=p

7. Assessment

The students' answers from the last phases of the demonstrator can be collected in a written form and provide information about the level and depth of the students' understanding and length of involvement in each phase.

In addition, the teacher can use Questionnaires in order to gauge the student's comprehension and gain of knowledge. The answers should be discussed with the students after the assessment.

The teacher can also ask the students to make their own questionnaires and each team can answer the other teams' questions.

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8. Possible Extension

The teachers and students could run an educational scenario using the giant solenoid magnet of the ATLAS experiment at CERN http://graasp.eu/ils/562a01a50fffcc3250f7f43d/?lang=en

This is based on bending charged tracks in the inner detector of the ATLAS detector and from the bending radius and their momenta determine the strength of the ATLAS solenoid field magnet

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

Some videos about CERN

https://www.youtube.com/watch?v=PHP13tTjidA

https://www.youtube.com/watch?v=sL3PK0kmD98

Picturing particles

https://www.youtube.com/watch?v=259asTAjts0

The CERN's microcosmos exhibition https://www.youtube.com/watch?v=ZB0vnP7uuko

The LHC accelerator

https://www.youtube.com/watch?v=b6CqmHREE1I&t=28s

The ATLAS detector

https://www.youtube.com/watch?v=ckARmttkTS4

https://www.youtube.com/watch?v=pQhbhpU9Wrg

CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.56 Demonstrator of how LHC works - Let's Accelerate Particles: learn about the LHC accelerator by playing a game

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	C.Kourkoumelis, G.Vasileiadis
Code:	D 3.2.56.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Motion of particles in electric and magnetic fields, acceleration of particles, High Energy Physics at CERN

1.2 Type of Activity

Workshop with students: Introduction to elementary particles followed by hands-on activity with PCs. The students follow interactively all stages of acceleration of particles by playing an educational game

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

Formal and informal

1.5 Effective Learning Environment

- Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
- Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work
- Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.
- Visits to research centres (virtual/physical)aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

2 Rational of the Activity / Educational Approach

- Introduction to High Energy Physics
- Understanding of scientific concepts and phenomena
- Active participation in modern physics research
- Emulation of cutting edge research work using playful learning environments
- Develop skills of teamwork

2.1 Challenge

School curriculum focuses on the fundamental concepts of physics. That is undoubtedly necessary as a basis to understand more complex concepts. However, focusing on discoveries made centuries ago and ignoring recent advances promotes an antiquated view of physics and fails to spark the students' interest towards it. It is necessary for them to learn how physics has evolved and what the current scientific view of the world around us is. This will not only give them a more complete view of what physics represents but also motivate them to take an interest in the physical sciences.

In this exercise, the students use an attractive learning environment which helps them to get acquainted with the most advanced technological equipment. They are expected to understand quite complicated processes which take place in order to operate the world's most powerful accelerator. They are also encouraged to collaborate with their teammate and answer knowledge and assessment questions.

2.2 Added Value

- Learn about the motion of charged particles in electromagnetic fields
- Understanding of scientific concepts and phenomena
- Familiarize themselves with cutting edge technology required to build world's most complicated accelerators
- Virtual visits to CERN and its experiments
- Live discussion with researchers at CERN
- Develop skills of teamwork

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3 Learning Objectives

School curriculum is usually limited to basic physics concepts that were discovered decades ago. While this is an important foundation for the understanding of modern physics, it also leaves the students with a very antiquated view of physics.

With this demonstrator we aim to present to the students a realistic view of how modern particle physics research is conducted at the most advanced particle accelerator in the world, the LHC, and its experiments. This will not only give students a detailed view of the advances in particle physics but will also teach them about the structure of matter, the existence of a multitude of subatomic particles and their interactions. In addition it introduces them to the most advanced technological progress and helps them understand the challenges and difficulties presented when particles are accelerated at unprecedented energies.

3.1 Domain specific objectives

The students will learn about subatomic particles and their interactions, the structure of matter and the four fundamental forces in nature. They will also learn how particles move in electric and magnetic fields and how large numbers of particles are focused together to produce pencilike beams. Finally they will visualize the products of collisions of such beams of particles.

3.2 General skills objectives

Students will learn to apply their knowledge of electric and magnetic forces in practice in order to achieve their ultimate goal guided along all steps by the professional LHC engineers.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

This demonstrator is created to give the students the opportunity to discover certain physics applications on their own. They have to gather the answers to the knowledge questions (the correct answers are provided afterwards) and draw conclusions based on them, the guidance of their teacher and the lectures they were given. They also have to prepare a report that outlines their results and discuss it with other students from different teams. In general the students are given as much freedom as possible to gather and interpret their own results and reach conclusions.

4.2 Student needs addressed

The students involved in this exercise should have basic knowledge of physics and electromagnetism. Also a basic knowledge of the structure of the atom (or even elementary particles) is desired. Students work on PCs using the LHC game (played using the Flash software) which is intuitive and easy to use. It is part of the software developed by CERN within the CERNland applications which include a number of other games for younger ages.

Students of ages 12-15 will enjoy playing the game.

5 Learning Activities & Effective Learning Environments

6 Question-eliciting activities

- Lecture about particle physics and accelerators as giant microscopes by experts
- Lecture about CERN and the LHC and accelerating techniques by experts
- Discussion/question/answer session with the students and teachers and experts from CERN

7 Active investigation

- Introduction to the different stages of the LHC game software that will be used
- LHC interactive game
- Possible video Conference with other schools (for students)
- Understanding of scientific concepts and phenomena
- Emulation of cutting edge research work
- Involvement in high end scientific research
- Develop skills of teamwork

More Specifically:

- Students will learn the principles of basic science, concepts beyond the school curriculum
- Students will learn through playing games.
- Students will engage in hands-on activities which will allow them to understand and become familiar with the work of physicists working in the field of high energy physics. They will learn about probing matter deeper and deeper using accelerators and different particle beams. They will also learn about the use of accelerators in everyday life (hospitals, sterilization etc).

Science topic: Electricity and Magnetism and Particle physics. (Not part of most national curriculums) Class information Year Group: Age range: 12-15 Sex: **both** Pupil Ability: **Basic computer usage required**	Materials and Resources: A computer laboratory with one pc for each student or group of 2 students. A projector. Internet connection. *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **In a laboratory equipped with PCs** *Health and Safety implications?* **None** *Technology?* ***PCs with Flash Player installed, A projector*** *Teacher support?* **It is desired that the teacher talks to the students before the activity takes place. This will make it easier for the students to absorb better the impact of the game.**
Prior pupil knowledge: **Basic understanding of electromagnetism, the basic forces and atomic structure**.	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* **The aim of the lesson is twofold. First the students will understand important principles of the structure of matter. Second they will learn that scientists at CERN try to further probe matter in subatomic dimensions and they will become familiar with the technological advances that help us uncover the mysteries of nature.** **As an additional outcome it can be combined with the art classes and the students to be asked to make their own visualization of the products of particle collisions and/or produce short artist videos which explain their findings.**	

Assessment Collect answer to knowledge and assessment questions	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* *By adjusting the duration of time spent in each phase and the discussion in between.*	**Key Concepts and Terminology** Subatomic particles, structure of matter, fundamental forces, electric and magnetic fields, interaction of particles with electromagnetic fields, particle accelerators, dipole and quadrupole magnets **Science terminology:**

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		-see above- **Arts terminology:** Particle collision visualization, Photographs, video, paintings

Session Objectives:
At the end of the session they should have completed successfully all the steps needed to accelerate and collide particles at the LHC. They should have answered correctly the knowledge and assessment questions. Finally they should have discussed with their teachers the applications of accelerators in everyday life.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question	The purpose of this introductory phase is to provoke the curiosity of the students by making them aware of the cutting edge research done at the European Center of Particle Physics (CERN). The principle idea is to point out the importance of this research as well as the difficulties humanity faces when studying nature. As soon as the goals of the scientists are understood, the question of "how is that made possible?" is the next natural step. They will, therefore, become familiar with the new technologies developed in order to construct and operate the giant accelerator and the experiments installed in it. To do so, they will try to answer general	Teachers should make a brief introduction to their students about the elementary particles, CERN, general concepts of basic research in High Energy Physics and engage them in watching videos about CERN and the LHC accelerator, since the main part of this activity focuses on understanding the principles behind the operation of particle accelerators and their applications in everyday life.	Possible initial collaboration with arts teachers to visualize elementary constituents of matter

		purpose teacher's questions, watch videos and use the web to gather more information.		
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	This Phase follows the general purpose introductory Phase 1. The aim of this Phase is to give students a broader understanding of the difficulties involved in achieving particle acceleration at High Energies. To do so, the interaction of particles with electromagnetic fields is presented in this phase. The behavior of different particles is studied based on scientific evidence. The process of accelerating particles is divided in three logical steps based on the behavior of particles in electromagnetic fields as well as the interactions between particles: 1) accelerating particles, 2) bending particles and 3) focusing particles.	The teacher has a lot of freedom when explaining the various concepts of this phase. He/she is expected to choose a procedure that best suits his/her school curriculum as well as the current level of the class. A general recommended approach when teaching these concepts is to present only the basic physical principles that govern the interaction of particles with each other as well as with fields, and then pose questions to the students that aim at extracting from them the optimal way to accelerate particles based on their physical properties and the constraints that stem from them. Naturally, the activity it self will provide the relevant guidance in order to achieve this goal.	Possible collaboration with arts teachers to visualize and draw particle accelerators

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using active investigation and *dialogue* with each other and the teacher to support their developing understanding.	This is the most interactive part of the demonstrator and the most important one since students will be asked to play a relatively easy game that requires implementation of the knowledge they gathered in the previous phases. The ultimate goal of the game is to accelerate particles in the LHC following the exact steps that scientists at CERN follow when accelerating beams of protons. The game is simple and well documented. The aim is to give practical meaning to the words "accelerating, bending and focusing particles" by actively engaging the students in this procedure.	Teachers are expected to have tried the game beforehand in order to guide the students through the various steps if needed. The teacher role in this part of the exercise is minimal. They should provide feedback to the students that need it and clarify any notions that haven't been understood. The use of the game provides a natural framework that the teacher can use in order to help him/her communicate and analyze the scientific concepts involved.	Collaborate with arts teachers to draw the effects of magnetic fields
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	The goal of this Phase is to make sure the students have mastered the relevant material. Some of the students will have understood the concepts exposed in this activity, whereas others might still have questions whether they choose to come forward with them or not. In this phase they are expected to be able to explain what happens when we try to accelerate particles, how and why it happens. Ultimately, they should work in groups of two (or more) in order to provide	The role of the teacher in this part of the exercise is vital. The teacher should try to guide the students by asking questions relevant to the problems and seeking solutions to these problems. He/she should promote teamwork in solving these problems. The utmost importance of the role of the teacher stems from the fact that he/she should try to understand what concepts of	Create short videos showing motion and focusing of particle beams

		suggestions for future particle accelerators.	the activity were not understood from the students, and guide them in understanding these concepts by asking the appropriate questions.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Phase 5 assumes that a thorough discussion took place in Phase 4, since now the students will be asked to compare the solutions that they proposed with the solutions that the scientific community has chosen for future accelerators. There are many physical concepts and restrictions that can be discussed in this Phase (the speed of light, particle radiation, etc).	The activity itself provides the necessary guidance a teacher may need in order to actively engage the students in this discussion. This is the Phase that the teacher is able to showcase some of the most fascinating ideas of Science and provoke the curiosity of the students for concepts that go beyond the scope of this activity. Phases 4 up to 7 can be extended as much as needed based on the interests of the teacher and the students.	Continue visualization using digital modes as well (photos, films)

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students compare their results with other students and discuss the results, the different approaches and the possible outcome of the various suggestions. Depending on the school infrastructure and the personnel availability, a remote connection with CERN can be established in this phase so that the students can expose their ideas to a scientist actively engaged with this research and ask questions or further guidance.	The teacher is the coordinator of this procedure and holds a secondary role as the main goal is to provoke student communication and exchange of ideas on a scientific background. At the end of this phase the teacher should highlight the fact that this is a model of the actual procedure followed by scientists when doing research.	Students discuss with both science and arts teachers as well as their fellow students their art work created during previous phases
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	The goal of this phase is to sum up the outcomes of the activity. The students could participate in non-competitive questionnaires in order to determine the amount of teamwork and the results produced from each group (scientifically valid suggestions, feasible future experiments, etc).	The goal of the teacher is to sum up the goals of the activity, the new concepts, the achieved results and the possible future applications of what the students learned during the exercise. He/she should also highlight once more the applicability of accelerators in modern life and the high expectations for future technological break-	The teachers together with the students select few examples in order to make a small exposition for their parents and the public in the form of a science fair

			throughs based on particle accelerators.	

6 Additional Information

- The game exists in different languages: French, English, German and Italian

7 Assessment

There are assessment questions embedded in the ISE LHC game demonstrator. The students' answers can be collected and provide information about the length of the student's understanding and length of involvement in each phase.

8 Possible Extension

There are several other games with the general framework of the CERNlab shttp://www.cernland.net/index.php?.

The Microboy game can also teach in a playful way the chemical composition of atoms.

A natural extension of this Demonstrator –but for older kids- is the HYPATIA demonstrator that studies the collisions of particles after they are accelerated to the desired energy.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9 References

http://home.cern/

http://home.cern/students-educators

http://cern50.web.cern.ch/cern50/multimedia/LHCGame/StartGame.html

http://home.cern/about/experiments

http://portal.opendiscoveryspace.eu/search-resources-in-community/817954

http://portal.opendiscoveryspace.eu/edu-object/lets-accelerate-particles-834785

D3.2.57 Particle Physics Masterclass

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Sophy Palmer, Elizabeth Cunningham (STFC)
Code:	D 3.2.57.	**Contributors:**
Version & Date:	Version 1 26/05/2016	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics

1.2 Type of Activity

School, university or research facility based – Masterclass held at national laboratory

1.3 Duration

1 day (the programme of the day is modular, and different components can be run independently)

1.4 Setting (formal / informal learning)

Both formal and informal settings - formal lectures, informal tours in small groups, workshop activity in teams, opportunities for questions throughout.

1.5 Effective Learning Environment

Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation

- Students and teachers will take part in computer workshops, using MINERVA visualization and analysis package.

Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

- Students and teachers are encouraged to question and interact with scientists and engineers during the workshop, tour and informal lunch session.

Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.

- Students and teachers will use real LHC data in order to discover properties of the Higgs Boson.

Visits to research centres (virtual/physical) aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

- Students and teachers will all have a guided tour around a particle accelerator, with a scientist or engineer working there.

Communication of scientific ideas to audience addressing the need to establish settings in which learners will be enhanced to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.);

promoting this way a dual channel of communication: a) reflective processes (self-engagement for scientific consistency and verification) and b) explicit elaboration of scientific ideas through interaction and 'extroversion'.

- Students and teachers will have a series of lectures and take part in an interactive quiz.

Arts-based which addresses and enhances scientific interconnection of science with aspects of art

- Students will be encouraged to take reflective photographs throughout the day and submit their most inspiring/interesting photograph with a caption (via social media) into a masterclass photography competition.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Particle physics and the work of the Large Hadron Collider are very inspirational topics and students are curious about the ongoing research. Often, though, teachers do not feel they have the knowledge and background to be able to answer their students' questions. The particle physics masterclass allows students, and teachers, to interact with the scientists and engineers working at the Large Hadron Collider, and gives them to opportunity to experience particle physics for themselves.

2.2 Added Value

The collaborative computer workshops use the MINERVA tool, which has been developed to help students learn more about the ATLAS experiment and particle physics at CERN. It is based on Atlantis, the event display used at ATLAS to visualise what happens in the detector. The aim of MINERVA is to give students a better understanding of how particle detectors work and the physics that they study. Currently, in MINERVA, students are able to study W and Z boson events by observing their decay products and apply this knowledge to search for the Higgs boson. By taking an inquiry based approach to finding the Higgs, this workshop enables students to experience what it is like to be a particle physics researcher.

The masterclasses give students the opportunity to interact with scientists and engineers in both formal and informal settings. During the tours and workshops students are in small groups and have the chance to question their guides and demonstrators.

Throughout the masterclass there are opportunities for the students and teachers to question the particle physicists working at CERN: both on the curriculum material and on further questions.

By asking the students to photograph what they find interesting throughout the day they will be able to express visually what has inspired them during the masterclass and capture a message that was important to them in a creative way.

By giving students the opportunity to visit some of the UK's particle accelerators, they will experience for themselves the size and scale of these facilities, learn more about the real-world impact of particle physics and accelerator research, and appreciate the fact that these facilities exist in the UK as well as at CERN.

The content of the masterclass is designed to link very closely to the English school curriculum in the final two years of school (age 16-18). This gives students and teachers more confidence to address and study these inspiring topics.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Particle Physics Masterclasses is to **inspire students with the cutting-edge and popular subject of particle physics.**

The domain specific objectives of the Particle Physics Masterclass are:

- Give students and teachers the chance to interact with particle physicists working with and at CERN
- Give students and teachers the chance to visit a large-scale particle accelerator in the UK (the ISIS Neutron and Muon Source, or Diamond Light Source), learning about the applications of particle physics
- Give students and teachers first-hand experience of 'big science' and allow them to appreciate both the scale of engineering involved and other applications of accelerator science
- Give students and teachers access to LHC data so that, working collaboratively within a group, they can discover the Higgs for themselves
- Assist teachers to build confidence in teaching relevant subjects

3.2 General skills objectives

The general skills objectives for the Particle Physics Masterclass are:

- Develop an understanding of scientific inquiry and careers
- Highlight the achievements of science and technology
- Understand the methodology that guides scientific investigation
- Value science and technology for its economic, social and cultural contribution to society
- Use photography to capture an image that is visually as well as scientifically interesting

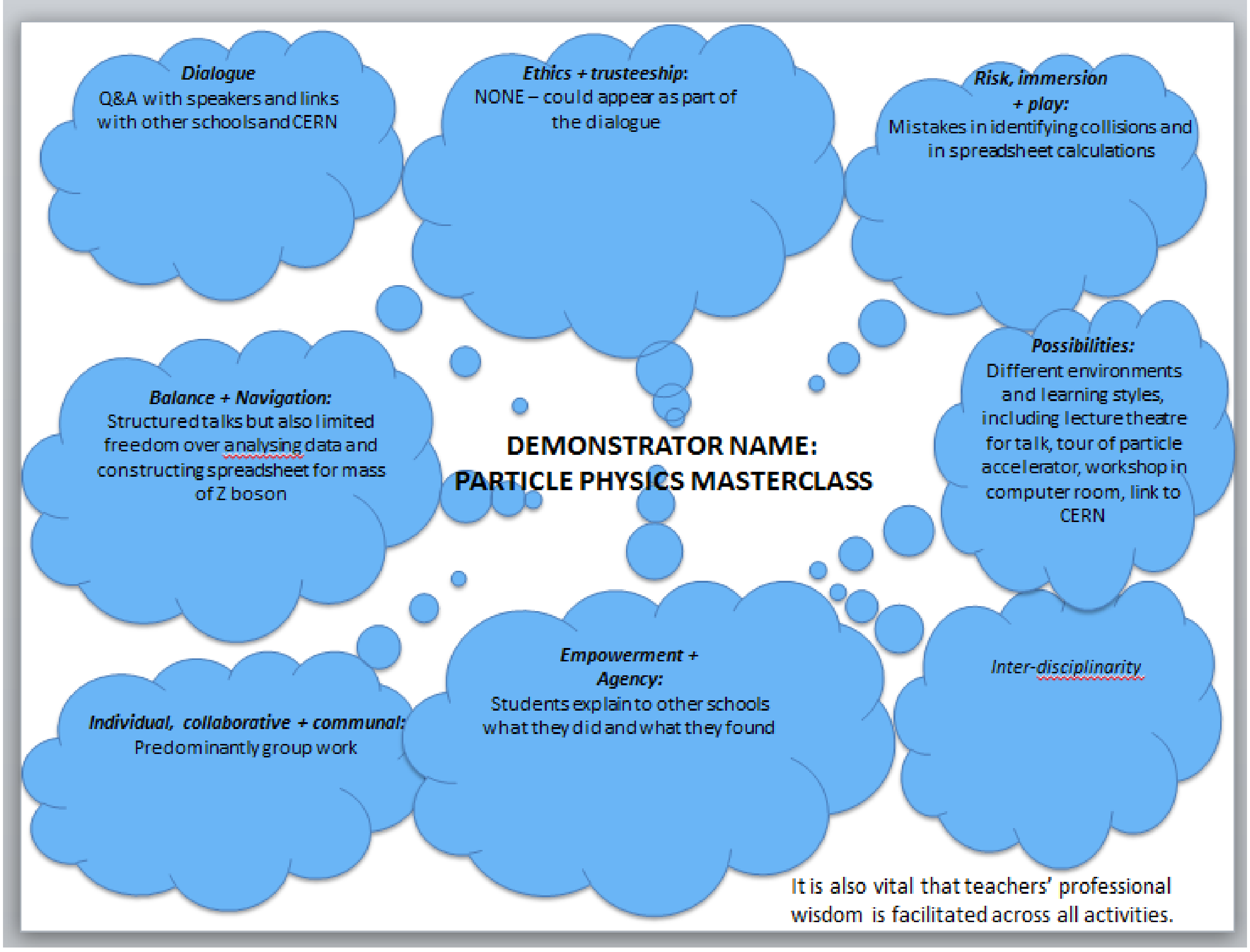
4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrators main aim is to engage 16-18 year old high school students studying physics and science teachers with particle physics through:

- Lectures and discussions with scientists and engineers (A very brief guide to accelerators, Fundamentals of particle physics, The Large Hadron Collider, Applications of accelerators)
- Hands on computer workshop using LHC data and the MINERVA tool
- Tour of particle accelerator in a small group
- Interactive quiz
- Photography competition

The masterclass improves the knowledge and confidence of both students and teachers in particle physics.



4.2 Student needs addressed

- Particle physics is a topic that interests and inspires, but which some teachers are not confident teaching.

- Using IBSE for the masterclass, allowing students to use real LHC data for themselves, acts to dispel the notion that 'particle physics isn't for me'.
- Gives students and teachers access to experts in what is considered to be a complicated field.
- Students are able to see how the direct applications of particle physics affect their lives.
- Students given the opportunity to highlight what is important to them through photography.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics **(Relevance to national curriculum) Key component of A level syllabus (UK students, age 16-18)** **Class information** **Year Group: Year 12 & 13 (sixth form)** **Age range: 16-18** **Sex: both** **Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.printed questionnaires, teleconference, etc.) Lecture facilities, computers with internet access, evaluation questionnaires.*** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Masterclasses will be held at your local particle physics group. Some of the activities can be adapted for the classroom.*** ***Health and Safety implications? Knowledge of local fire and radiation procedures.*** ***Technology? Computer and internet access. Voting pads (for the quiz).*** ***Teacher support? Reference material.***

Prior pupil knowledge

- **Basic ICT skills**
- **Commitment to attend the full day's event**

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*
During this scenario, students will:
Lectures: Learn about: the principles and applications of particle accelerators, fundamentals of the standard model, large hadron collider.
Tour: Experience a real particle accelerator. Appreciation of the real world applications of particle physics – in engineering, chemistry and the life sciences as well as physics.
Workshop: Empowerment from using real LHC data to solve a challenge and appreciation of collaborative nature of scientific research.

Assessment **Quiz to test their scientific knowledge and understanding.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** **Science terminology:** Maths, Particle and Accelerator physics.

Student questionnaire. **Teacher e-survey**	All the students do the same activities, there are opportunities for students to ask questions and clarify points throughout the day.	**Arts terminology:** **Photography**

Session Objectives:
During this scenario, students will deepen their understanding of particle physics concepts and phenomena, through both formal and informal sessions.
Masterclasses encompass the CREATIONS features of creativity: including dialogue; risk, immersion and play; possibilities; empowerment and agency; individual, collaborative and communal; balance and navigation.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION: students investigate a scientifically oriented question**	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students will engage with lecturers, tour guides and workshop leaders, creating a dialogue between students and scientists / engineers	Teachers will engage along with their students	
Phase 2: **EVIDENCE: students give priority to evidence**	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will explore real data from the LHC	Teachers will explore real data from the LHC	

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Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will analyse the LHC data using MINERVA – based on ALAS event display. Students work collaboratively in teams – both within their school groups and, when combining data, across different schools.	Teachers will support their students throughout the analysis, alongside workshop leaders	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students use the data they have analysed to find the Higgs boson and determine its mass.	Teachers work alongside their students.	
Phase 5: **CONNECT: students connect explanations to scientific knowledge**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students use the knowledge they have learned in class and during the masterclass lectures to interrogate the data and their analysis of it.	Teachers encourage their students to connect their background information with the data and analysis work they have been undertaking.	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	During the final phase of the MINERVA workshop, different teams of students come together to communicate their findings and work	Teachers work alongside their students, encouraging them to contribute to	

		together to find a final result.	the final group discussion.	
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students will take part in an interactive quiz based on all aspects of the masterclass.	Teachers will take part in the quiz alongside their students	**Students will be encouraged to take reflective photographs throughout the day and submit their most inspiring/ interesting photograph with a caption (via social media) into a masterclass photography competition.**

6. Additional Information

Further information can be found at:

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

7. Assessment

- Students and teachers will undertake an interactive quiz to gauge their learning from the masterclass.
- CREATIONS evaluation (student and teacher questionnaire) will be used to evaluate the masterclass.

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8. Possible Extension

Students will be encouraged to explore the LHC for themselves by visiting

https://www.higgshunters.org/

so that they can become involved in further analysing LHC data, as part of the citizen science project.

Teachers can engage in further projects, such as:

- CERN@school
  - A project that brings technology from CERN into the classroom, allowing students to design and analyse their own experiments
  - https://cernatschool.web.cern.ch/
- HiSPARC
  - HiSPARC is a project in which secondary schools and academic institutions join forces and form a network to measure cosmic rays with extremely high energy.
  - http://www.birmingham.ac.uk/schools/physics/outreach/HiSPARCproject.aspx

These projects will allow teachers and their students to continue engaging with particle physics in an empowering, IBSE-based manner.

9. References

Further information can be found at:

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

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http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

D3.2.58 Crater Investigation

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Sophy Palmer, Elizabeth Cunningham
Code:	D 3.2.58.	**Contributors:**	
Version & Date:	V 2 01.09.2017	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Art

1.2 Type of Activity

Educational Activities based on Creativity - enriched Inquiry Based Approaches (school based).

1.3 Duration

Two hours (can be extended)

1.4 Setting (formal / informal learning)

Formal learning (school-based)

1.5 Effective Learning Environment

- Simulation/Experimentation
- Arts-based

2 Rationale of the Activity / Educational Approach

2.1 Challenge

'The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report (Rocard, 2007) brought science and mathematics education to the top of educational goals of the member states (following similar actions in US in 1996 NRC, 1996 , EDC Center for Science Education, 2007). The authors argue that school science teaching needs to become more engaging, based on inquiry based and problem solving methods and designed to meet the interests of young people. ***According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at schools.****'*

Taken from: D4.2 Schools- Research Centers Collaboration Future Challenges Report

This demonstrator aims to meet this challenge by teaching students about craters, comets and meteorites in an inquiry based, engaging, hands on and relevant way using experimentation and arts-based learning:

- by looking at the effects of impacts on the Earth and in the Solar System – making it relevant by linking to the extinction of the dinosaurs, craters on the Moon (they can see) and meteorites (they can hold)
- enabling pupils to design their own experiments to investigate how meteorite impacts leave craters on the planets – through inquiry based investigations and hands on simulations
- encouraging the pupils to apply the knowledge and ideas they have gained through their experiments to create their own artwork: deciding on what artistic techniques should be used to represent different scientific ideas – through arts based exploration.

2.2 Added Value

In this demonstrator students will investigate how meteorite impacts leave craters on the planets, by simulating the meteorite as a small object (marble, ball, stone) and dropping it into a tray with layers of different material (flour, coloured sand, cocoa powder). They investigate the effects of different variables (e.g. height dropped, size of object, angle of descent, material of object) and draw conclusions about how craters form.

- This hands-on learning experience in crater creation strengthens the inquiry process in the student group and allows them to apply the 'question', 'evidence', 'analyse', 'explain' and 'communicate' phases of the IBSE cycle.
- Throughout the investigation pupils are exploring the scientific method and must be self-critical of their approach to make sure they investigate different variables in a consistent and scientific way.

Pupils then apply the knowledge and ideas they have gained from their simulations to create their own artwork: deciding on what materials and techniques should represent the planet, what objects should represent the meteorite, how to drop the objects etc. in order to achieve the desired artistic effect. Photographs of the resulting art can be taken and displayed.

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Pupils will use what they learn through scientific investigation in order to create their own individual artwork. This will reinforce the learning objectives of the first (IBSE) half of the demonstrator and allow the pupils to use their scientific knowledge to develop an artistic display piece.

- The artistic conclusion of the session enables students to engage with the 'risk, immersion and play' CREATIONS feature.
    - By going beyond the scientific investigation the pupils can immerse themselves in what they have learned and express it in a playful and artistic way.
    - This artistic process will support discipline knowledge in both the science and arts.
    - The risks associated with misconceptions or individuals applying scientific knowledge to an artistic design leading to incorrect analogies can be mitigated by comparing artistic pieces within the group at the end, discussing the artistic choices and the scientific reasons behind them.
    - This will reinforce the scientific learning as well as check for inaccuracies or misunderstanding in the student knowledge.
- The combination of arts and science based learning also utilises the power of the 'Interdisciplinary' CREATIONS feature, both in the session itself and for primary school teachers to take back to the classroom and run a cross-curricula lessons, incorporating elements from both the science and art curricula.

In summary, as well as the scientific knowledge of craters, comets and meteorites, this demonstrator will specifically enable students to gain:

- Experience of inquiry based learning, explicitly the 'question', 'evidence', 'analyse', 'explain', 'communicate' phases of the IBSE cycle.
- Skills to design and carry out an investigation using scientific principles.
- The ability to express scientific ideas and principles in an artistic and playful way – with an awareness of the possibility of misconceptions.
- Knowledge of the interdisciplinary nature of arts and science.

3 Learning Objectives

3.1 Domain specific objectives

The craters demonstrator domain specific objectives are:

- Get students interested in science and research through artistic play.
- Teach students about craters, comets and meteorites using experiments and arts-based learning.
- Teach students to design and carry out an investigation using scientific principles.
- Open students to the process of expressing scientific ideas and principles in an artistic and playful way.
- Teach students about the interdisciplinary nature of arts and science.

3.2 General skills objectives

In the context of the craters activity, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena via simulations and experiments
- Scientific interconnection of science with aspects of art
- Develop spirit of cooperation and teamwork
- Connect the science classroom with scientists, research and space missions

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4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to motivate pupils who are not typically engaged with science by allowing them to use their own conclusions in order to create a piece of artwork in a lively and unusual fashion.

4.2 Student needs addressed

In order to achieve the learning objectives of the craters demonstrator students will need to be supported by:

- Introducing the relevant scientific knowledge and principles at the beginning of the session
    - teaching students about craters, comets and meteorites by looking at the effects of impacts on the Earth and in the Solar System and making it relevant by linking to the extinction of the dinosaurs, craters on the Moon (they can see) and meteorites (they can hold).
- Enabling them to design and carry out their own investigation using scientific principles

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  - engaging the students in collaborative discussion and enable them to build constructively on each other's ideas to enhance the design of their experiment
  - ensure their engagement in applying inquiry–based approaches like scientists and developing research questions and methodologies to address a scientific problem.
- Open students to the process of expressing scientific ideas and principles in an artistic and playful way
  - provide a safe and encouraging environment for students to express their learning in a creative way
  - supply the students with enough resources so their creativity and artistic design are not restricted
  - enable students to showcase their designs and encourage celebration and evaluation of what is produced.
- Teach students about the interdisciplinary nature of arts and science
  - Reinforce how the session is strengthened by including both the scientific and artistic elements.

5 Learning Activities & Effective Learning Environments

Science topic: Solar system science, energy and energy transfer, conducting scientific investigations. (Relevance to national curriculum) These topics link directly to the Key Stage 2 English curriculum (age 9-11) Class information Year Group: England Years 5-6 Age range: 9-11 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • Printed worksheets for the investigation • Plastic Gratnell Tray • Flour • A selection of other granular substances (e.g. coloured sand, cocoa powder, strawberry Nesquik) • Rulers • Kebab sticks • A selection of small objects (e.g. marbles, pebbles) • (optional) camera • (optional) powerpoint slides *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The learning can take place in any classroom situation. *Health and Safety implications?* The activity risk assessment highlights the importance of ensuring that the classroom floor remains clear and free of dropped objects (e.g. marbles), as well as the necessity of clear communication regarding the substances used, in case any of the participants have a severe gluten allergy. *Technology?* (Optional) Computer and projector, camera

	Teacher support? Reference material, teacher notes

Prior pupil knowledge

None necessary

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

- Understand that our planet, and other solar system bodies, have been impacted by meteorites over its history, which has affected our world and environment
- Understand the effects of different variables (e.g. height, width, weight of 'meteorite' object) on the subsequent crater
- Create a piece of art designed and made using their recently gained understanding

Assessment	**Differentiation**	**Key Concepts and Terminology**

The pupils complete an investigation worksheet (including results, diagrams, conclusions). Student questionnaire. Teacher questionnaire.	*How can the activities be adapted to the needs of individual pupils?* All pupils have the same objective – to understand the effect of different variables on impact craters. More able pupils should investigate a greater number and variety of variables, and consider the underlying principles of energy transfer etc. in more depth. Students will also be engaged in artistic/creative activities; allowing space for students to express themselves differently.	**Science terminology:** Crater. Meteorite. Energy. Variable. **Arts terminology:** Design. Materials.

Session Objectives:

During this scenario, students will deepen their knowledge of the solar system and the interactions between bodies, conduct their own scientific investigation and create artwork based on their conclusions.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1:	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through	Pupils will learn from their teacher about the	The teacher will introduce the	The teacher will explain

QUESTION: students investigate a scientifically oriented question	*dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	solar system, and discuss what could affect an impact crater on Earth and other planets / solar system bodies.	topic and challenge the students to discuss potential variables that affect the nature of impact craters.	the artistic challenge at the start of the activity - that pupils will create a piece of artwork by dropping their chosen objects (meteorites) into their chosen impact substance layers (planet). Students will discuss and question which materials (colours / textures etc.) and objects (weight / shape) they want to use to achieve

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				their desired creation.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils conduct simulations/experiments that model meteorite impacts, ensuring that the experiment is fair and rigorous.	Teachers stress the importance of a fair test throughout the session, and ensure that accurate data is kept, and diagrams are appropriately labelled.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils discuss and record their results regarding the effect of different variables on impact craters	Teachers ensure that conclusions are clearly recorded.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils draw on the data they have collected to develop conclusions for how meteorites create impact craters		Pupils will decide on their desired materials for their art project, explaining their choices and reasoning.

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils develop reasoning behind their conclusions (i.e. why dropping a 'meteorite' from a larger height creates a deeper crater)	.	Pupils describe why they want to create a piece in a particular style, and hence why they have chosen their materials.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Each investigation group should share their conclusions with the whole class, discussing any differences that have been found.		Students will decide on a process for creating their artwork, reporting this either via a written document or through discussions / presentations with the class.
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as	Pupils discuss what else they could do to improve their	The teacher leads a discussion on	Pupils use the knowledge they have gained to create their

REFLECT: students reflect on the inquiry process and their learning	that between open-ended inquiry learning and the curriculum and assessment requirements of education.	investigation, results and conclusions	the investigation, including ideas on how to improve it in the future.	own artwork by dropping chosen 'meteorites' into surfaces that they have chosen. The artwork can be displayed in various forms.

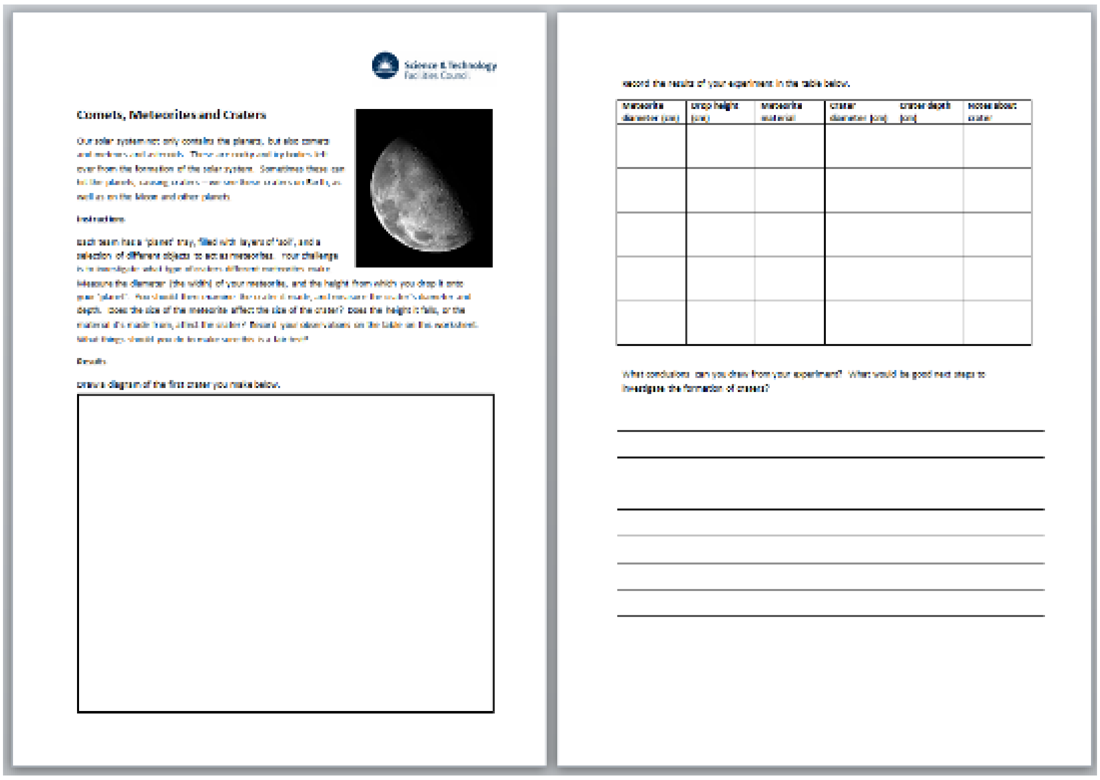
6 Additional Information

This activity has been run several times at the STFC Rutherford Appleton Laboratory.

While students are generally interested to learn about craters, comets, meteorites etc they became much more enthusiastic when given the opportunity to begin the hands on experiment. They fully engage with the discussions around: 'what effect changing different parameters might have' and are curious to test their hypothesis and examine the results.

Students are also proud of the art work they create and speak enthusiastically about how the different coloured materials created different effects for different sized impactors. Allowing the students to create something for themselves at the end of the session gives them more ownership over what they have learned and allows them to have a personal impact on the outcomes of the session.

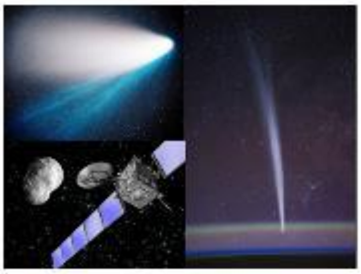
- Craters investigation worksheet: Craters-worksheet.docx


Science & Technology Facilities Council

Comets, Meteorites and Craters

- Introductory powerpoint slides: Craters-slides.pptx

CREATIONS has received funding from the European Commission HORIZON2020 Programme



Top left: Comet [illegible]

Bottom left: (ESA) In 2014 a spacecraft named Rosetta, after travelling through space for 10 years, arrived at Comet 67P/Churyumov-Gerasimenko to find out more about it. It sent down a little robot lander named Philae.

Right: APOD 2012 December 31

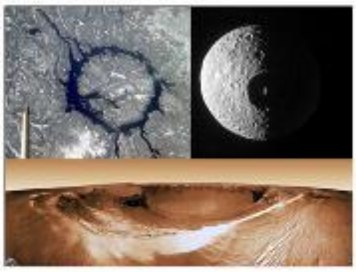
Comet Lovejoy and the ISS

Normally meteors are small so nothing much happens when they hit the ground. Sometimes, though, they're big enough to make a crater.

We think that a really big meteorite once hit the Earth – leading to the extinction of the dinosaurs.

APOD: July 11, 1999

Explanation: What happens when a meteor hits the ground? Usually nothing much, as most meteors are small and ... However, a large meteor created Barringer Meteor Crater in Arizona, pictured above. Barringer is over a kilometer across. In 1920, it was the first feature on Earth to be recognized as an impact crater. Today, over 100 terrestrial impact craters have been identified. Recent computer modelling now indicates how some of the Canyon Diablo impactor melted during the impact that created Barringer.



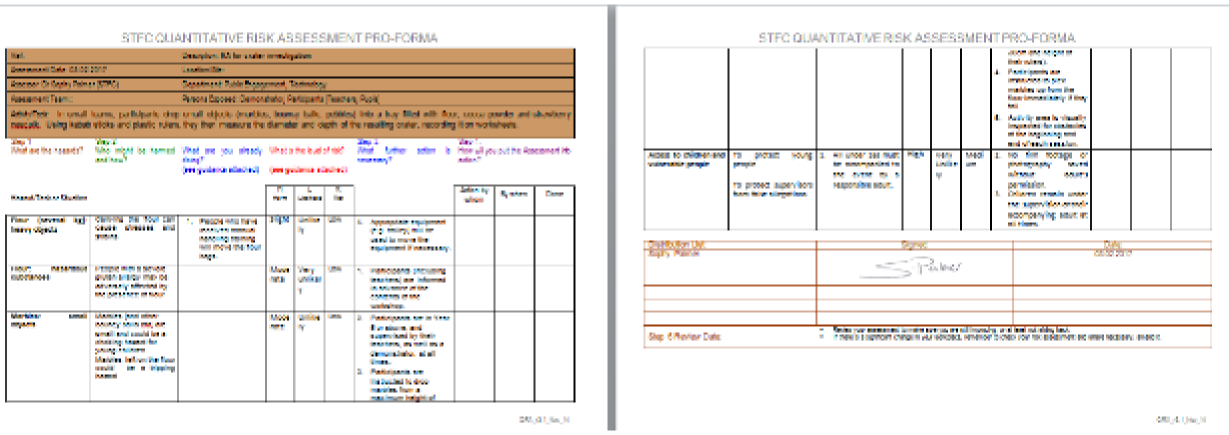
Instead, we make a model. We do this in lots of different ways – we can use computers, or do other experiments. WE even make pretend stars with lasers at RAL.

CLICK For today we're going to use something a bit smaller

CLICK Trays filled with flour for the planet

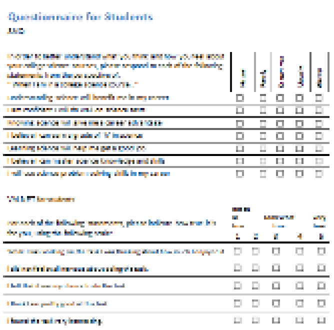
CLICK Marbles or other balls for the meteorite

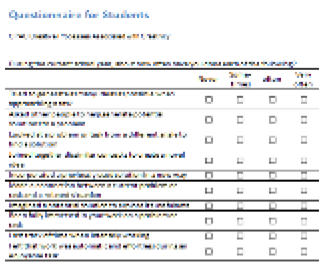
- Risk assessment for activity: RA_Craters.doc

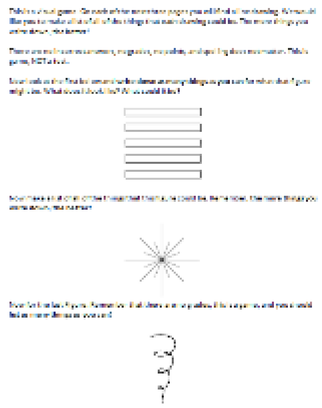


7 Assessment

- Pupils will complete an investigation report, which can be kept by the teacher as a record of their achievements
    - This assessment will record the experimental methodology used by the students and establish whether the students successfully designed and carried out an investigation using scientific principles.
- Pupils will complete some artwork – either the piece itself, or photographs of it, can be kept as a record for assessment.
    - This assessment will demonstrate whether the student fully engaged with the process of expressing scientific ideas and principles in an artistic and playful way.
- The CREATIONS post questionnaire will be given to students after the activity.
    - This assessment will identify the students' attitudes towards the activity, science as a career and the creative methods used.


Questionnaire for Students


Questionnaire for Students



8 Possible Extension

- An investigation of craters, and folklore about craters, on Earth.
- Write a story or a play or a poem about a meteorite impact.
- An investigation of craters on other planets, and how we stud them.
- Visit a relevant science or discovery centre.
- Follow up online investigations:
    - using impact simulator e.g. http://simulator.down2earth.eu
    - using google maps to search for crater candidates on the surface of the Earth e.g. https://en.m.wikipedia.org/wiki/List_of_impact_craters_on_Earth

9 References

D3.2.59 Dark Matter Particles Investigation

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Sophy Palmer, Elizabeth Cunningham
Code:	D 3.2.59.	**Contributors:**	Konstantinos Nikolopoulos, Maria Pavlidou
Version & Date:	V 2 01.01.2018	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

This demonstrator is based on the University of Birmingham demonstrator: "Particle Physics Workshop".

1.1 Subject Domain

Physics, Art

1.2 Type of Activity

Local Educational Activities based on creativity - enriched Inquiry Based Approaches (school based).

1.3 Duration

Two hours (can be extended / shortened)

1.4 Setting (formal / informal learning)

- Introduction: Formal learning (school-based presentation)
- Conclusion: Informal learning (group-based in school setting)

1.5 Effective Learning Environment

- **Visits to research centres (virtual/physical):** The activity includes virtual visits through video to the Boulby Underground Laboratory. The pupils are encouraged to explore the consequences of working in such an unfamiliar environment.
- **Simulation/Experimentation:** The activity includes an investigation into the properties of materials.
- **Arts-based**: The design and creation of the dark matter particles, incorporating the known properties of dark matter, allows the pupils to express themselves artistically.
- **Communities of practice (web-based/physical)**: Class works together throughout the activity
- **Dialogic space / argumentation**: Pupils discuss their interpretation of the properties of dark matter, using their dark matter particles. They also discuss the various types of scientific research carried out at the Boulby Underground Laboratory.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

'The publication of the "Science Education Now: A renewed Pedagogy for the Future of Europe" report (Rocard, 2007) brought science and mathematics education to the top of educational goals of the member states (following similar actions in US in 1996 NRC, 1996 , EDC Center for Science Education, 2007). The authors argue that school science teaching needs to become more engaging, based on inquiry based and problem solving methods and designed to meet the interests of young people. ***According to the report, the origins of the alarming decline in young people's interest for key science studies and mathematics can be found, among other causes, in the old fashioned way science is taught at schools.'***

Taken from: D4.2 Schools- Research Centers Collaboration Future Challenges Report

Students often disengage with science teaching as they perceive the topic as simply a list of facts, which they have to memorise: that all questions have been answered. This demonstrator aims to meet this challenge by teaching students about dark matter – one of the biggest unanswered questions in modern science – in an engaging, hands-on and relevant way using arts-based learning, relating it to science in the primary school curriculum. It clearly demonstrates that science is not static – that the scientific community is learning and trying to understand more all the time, and that there is a real chance that they, the student, can contribute to our understanding of our Universe.

2.2 Added Value

In this demonstrator students will learn about the work of the Boulby Underground Laboratory – searching for dark matter among other things. Dark matter is one of the biggest unanswered questions of modern science: it accounts for approximately a quarter of the Universe, but as yet we do not know what is consists of. By focussing on this topic, the demonstrator not only engages pupils with the 'big questions', but also is an excellent example of the idea that there are still many things for scientists to know, dispelling the intimidating stereotype of the 'all-knowing' scientist. It allows pupils to explore the 'how science works' aspect of the UK National Curriculum.

Pupils apply the knowledge and ideas they have gained from the introduction (which incorporates a virtual visit to the Boulby Underground Laboratory – an exciting and unique location) and investigation to create their own artwork: deciding on what materials and techniques should represent dark matter, keeping the properties of dark matter in mind. Photographs of the resulting art can be taken and displayed.

The artistic aspect of the session enables students to engage with the 'risk, immersion and play' CREATIONS feature. This will reinforce the learning objectives of the IBSE part of the demonstrator and allow the pupils to use their scientific knowledge to develop an artistic display piece.

- By going beyond the scientific investigation the pupils can immerse themselves in what they have learned and express it in a playful and artistic way.
- This artistic process will support discipline knowledge in both the science and arts.

- The risks associated with misconceptions or individuals applying scientific knowledge to an artistic design leading to incorrect analogies can be mitigated by comparing artistic pieces within the group at the end, discussing the artistic choices and the scientific reasons behind them.
- This will reinforce the scientific learning as well as check for inaccuracies or misunderstanding in the student knowledge.

- The combination of arts and science based learning also utilises the power of the 'Interdisciplinary' CREATIONS feature, both in the session itself and for primary school teachers to take back to the classroom and run a cross-curricula lessons, incorporating elements from both the science and art curricula.

In summary, as well as the scientific knowledge of dark matter and the work at Boulby Underground Laboratory, this demonstrator will specifically enable students to gain:

- Experience of inquiry based learning, explicitly the 'question', 'evidence', 'analyse', 'explain', 'communicate' phases of the IBSE cycle.
- Skills to design and carry out an investigation using scientific principles.
- The ability to express scientific ideas and principles in an artistic and playful way – with an awareness of the possibility of misconceptions.
- Knowledge of the interdisciplinary nature of arts and science.

3. Learning Objectives

3.1 Domain specific objectives

The dark matter particles demonstrator domain specific objectives are:

- Interest pupils in science and research through artistic play.
- Teach pupils about the search for dark matter and the properties of materials using experiments and arts-based learning.
- Make pupils aware that science still has many unanswered questions, and that a large part of the Universe is unknown.
- Open pupils to the process of expressing scientific ideas and principles in an artistic and playful way, and the important of imagination in science.
- Teach pupils about the interdisciplinary nature of arts and science.

3.2 General skills objectives

In the context of the dark matter particles activity, students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Scientific interconnection of science with aspects of art
- Develop spirit of cooperation and teamwork
- Connect the science classroom with scientists, research and laboratories

4. Demonstrator characteristics and Needs of Students

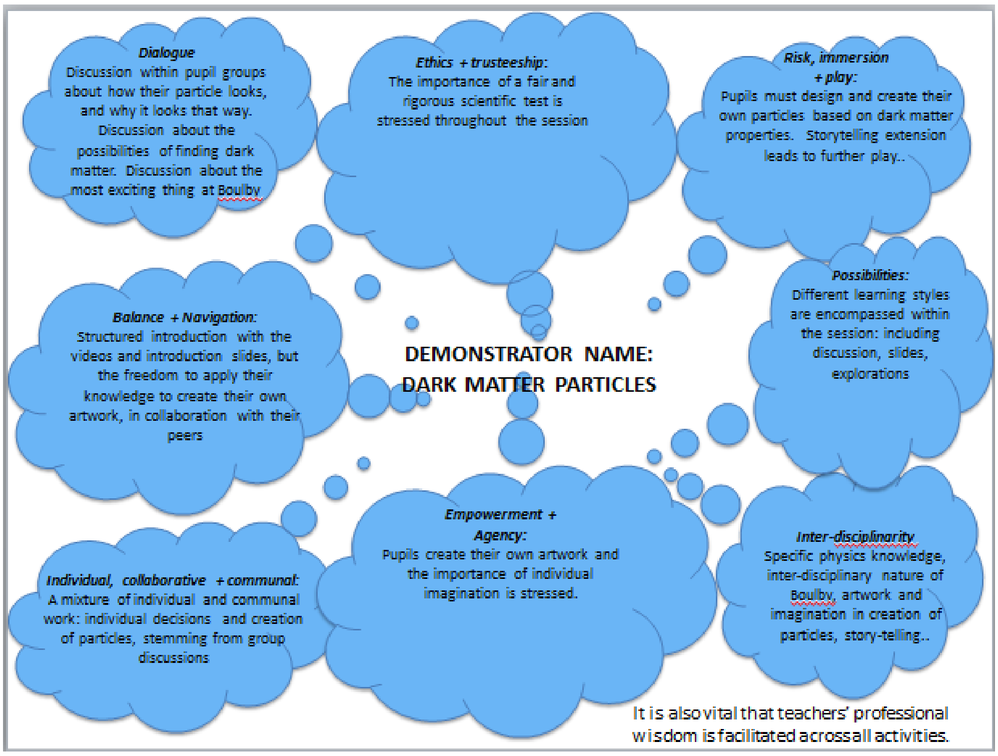
4.1 Aim of the demonstrator

The aim of the demonstrator is to motivate pupils who are not typically engaged with science by allowing them to use their own conclusions in order to create a piece of artwork in a lively and unusual fashion. It will do this in the following manner:

- The initial part of the activity is a set of prepared slides and videos including virtual visits to the Boulby Underground Laboratory, introducing the concept of dark matter.
- In groups the pupils investigate the properties of a series of 'mystery' objects (hidden from view in cardboard boxes with a small hand-hole). This links to the primary school science curriculum in the UK, and is used to demonstrate how we investigate the properties of dark matter without being able to see it.
- Pupils then design and create their own dark matter particles, choosing how to represent the known properties of dark matter, which are given in the prepared slides.
- A final slide and video explains some of the other research that takes place in the Boulby Underground Laboratory, and pupils are invited to consider the most exciting thing about the lab, and draw a picture representing that.

This demonstrator allows the teacher to engage their pupils' curiosity and creativity. The demonstrator encourages pupils to apply the knowledge and ideas they have gained through the introduction and investigation to create their own dark matter particles through arts based exploration.

The CREATIONS features are embedded within this demonstrator:



4.2 Student needs addressed

In order to achieve the learning objectives of the dark matter particles demonstrator pupils will need to be supported by:

- Introducing the relevant scientific knowledge and principles at the beginning of the session, through slides and video
    - teaching pupils about dark matter, and engaging their interest in the unusual environment of the Boulby Underground Laboratory
- Enabling them to design and carry out their own investigation using scientific principles
    - engaging the students in collaborative discussion and enable them to build constructively on each other's ideas to enhance the design of their experiment
    - ensure their engagement in applying inquiry–based approaches like scientists and developing research questions and methodologies to address a scientific problem.
- Open students to the process of expressing scientific ideas and principles in an artistic and playful way
    - provide a safe and encouraging environment for students to express their learning in a creative way
    - supply the students with enough resources so their creativity and artistic design are not restricted
    - enable students to showcase their designs and encourage celebration and evaluation of what is produced.
- Teach students about the interdisciplinary nature of arts and science
    - Reinforce how the session is strengthened by including both the scientific and artistic elements.

5. Learning Activities & Effective Learning Environments

Science topic: Properties of materials, dark matter, conducting scientific investigations. (Relevance to national curriculum) These topics link directly to the Key Stage 2 English curriculum (age 9-11) Class information Year Group: England Years 5-6 Age range: 9-11 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *What do you need? (e.g.* printed questionnaires, teleconference, etc.) • Printed worksheets for the investigation and design on the dark matter particle • 'Mystery' objects (e.g. stones, marbles, cotton wool) placed in boxes with hand holes (so that pupils can touch the objects without seeing them) • Slides and videos • Play pit balls • Craft materials (feathers, stickers, googly eyes etc.) • Pens, pencils, scissors, sellotape *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The learning can take place in any classroom situation. *Health and Safety implications?* Craft activity – see risk assessment (RA_MakingDarkMatterParticles.docx). No specific risks *Technology?* Computer and projector(optional: camera to record artwork) *Teacher support?* Reference material, slide notes

Prior pupil knowledge

None necessary, but this can be a revision or introduction of the 'properties of materials' topic of the primary school curriculum

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

- Understand that our Universe contains more than the 'normal' things they can see (stars etc), but also contains dark matter, which we cannot see
- Understand the scientists can investigate the properties of dark matter even though we cannot see it, and conduct an investigation into the properties of objects they cannot see
- Create a representation of dark matter based on its known properties
- Draw the most exciting part of the research at the Boulby Underground Laboratory

Assessment	Differentiation	Key Concepts and Terminology
The pupils complete an investigation worksheet. The pupils will create a representation of dark matter (both as a design and a physical piece of art). The pupils will draw a picture of their favourite piece of research at the Boulby Underground Laboratory.	*How can the activities be adapted to the needs of individual pupils?* All pupils have the same objectives – to learn about dark matter and the properties of materials. More able pupils should investigate a greater number of 'mystery' objects, and investigate using a greater variety of techniques. Students will also be engaged	**Science terminology:** Dark matter, property, material **Arts terminology:** Design. Materials.

Student questionnaire. Teacher questionnaire.	in artistic/creative activities; allowing space for students to express themselves differently.	

Session Objectives:

During this scenario, students will deepen their knowledge of the Universe and the Boulby Underground Laboratory. They will relate their own investigations into the properties of hidden objects to the investigations scientists undertake into the properties of dark matter.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design	Pupils will learn from the introduction (videos/slides) about dark matter, and discuss how to investigate the properties of materials they cannot see.	The teacher will introduce the topic and challenge the students to discuss ways to investigate unseen objects. The teacher can encourage discussion of	

	and collaborative work, as well as in the initial choice of question.		how different properties can be represented.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Pupils conduct experiments to investigate the properties of objects which they cannot see, ensuring that the experiments are fair and rigorous.	Teachers stress the importance of a fair test throughout the session, and ensure that accurate data is kept, and diagrams are appropriately labelled.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Pupils discuss and record their results investigating 'mystery' objects and speculate on what the objects are.	Teachers ensure that conclusions are clearly recorded.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Pupils draw on the data they have collected to develop conclusions for what the objects are. Pupils will decide on their desired materials for their art project, explaining their		

		choices and reasoning.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Pupils connect their investigation of hidden objects to the work scientists do to understand the properties of dark matter. They connect the properties of dark matter with their artistic representations of dark matter. Pupils describe why they want to create their representation of dark matter in a particular style, and hence why they have chosen their materials.	.	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Each investigation group should share their conclusions with the whole class, discussing any differences that have been found.		Students will decide on a process for creating their artwork, and explain their ideas to their group and the class.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Pupils discuss what else they could do to improve their investigation, results and conclusions	The teacher leads a discussion on the investigation, including ideas on how to improve it in the future.	Pupils use the knowledge they have gained about the properties of dark matter to create their own representation of dark matter. The artwork can be displayed in various forms.

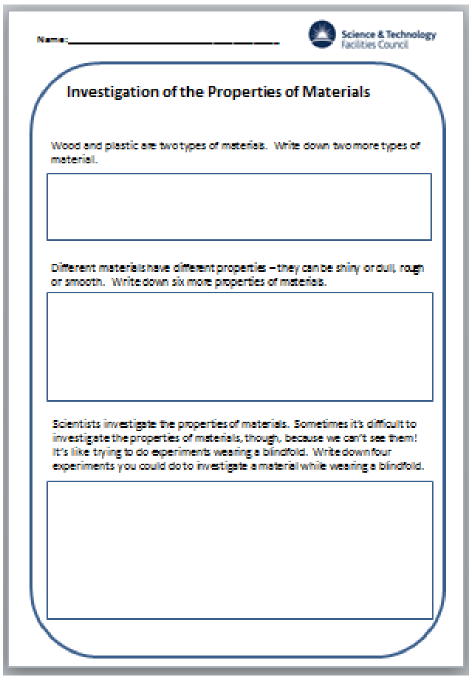
6. Additional Information

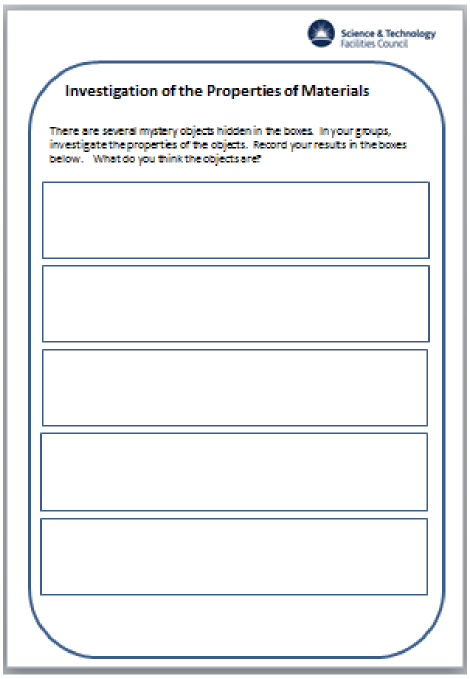
This activity has been run several times at the STFC Rutherford Appleton Laboratory.

While students are generally interested to learn about dark matter they became much more enthusiastic when given the opportunity to begin the hands on activity. They fully engage with the discussions around: 'what are the different properties of dark matter and how can I represent them' and are curious to see their own and their classmate's creations.

Students are also proud of the art work they create and speak enthusiastically about how the different designs represent different aspects of dark matter. Allowing the students to create something for themselves at the end of the session gives them more ownership over what they have learned and allows them to have a personal impact on the outcomes of the session.

- Properties of materials investigation worksheet: MaterialPropertyInvestigation.pptx





- Introductory PowerPoint slides: DarkMatterParticles-KS2.pptx

[illegible]

[illegible]

[illegible]

Chris and the team go all that way to try to catch Dark Matter – with this cool experiment!

To do this experiment, Chris had to think about all of the properties of dark matter. From our observations, we know that dark matter is:

- Made up of lots and lots of tiny tiny particles, even smaller than an atom
- We know that each of those tiny particles is quite heavy
- We know that those particles are not magnetic
- We know that they pass straight through us! In fact, if you hold your hands out, 20 million dark matter particles pass through them every second!
- We know that they're very mysterious

We use all of these properties, but we also use our imaginations. We have to imagine how dark matter could behave – and then do an experiment to catch it!

[illegible]

[illegible]

What do you think the most exciting thing about Boulby is?

Play competition video [Children are asked to draw whatever they think is most exciting about Boulby. The pictures will go on the wall of the lab and the winning picture will get a skype visit to the lab with Chris. The winner will also get a miner's helmet and piece of rock salt from the mine.]

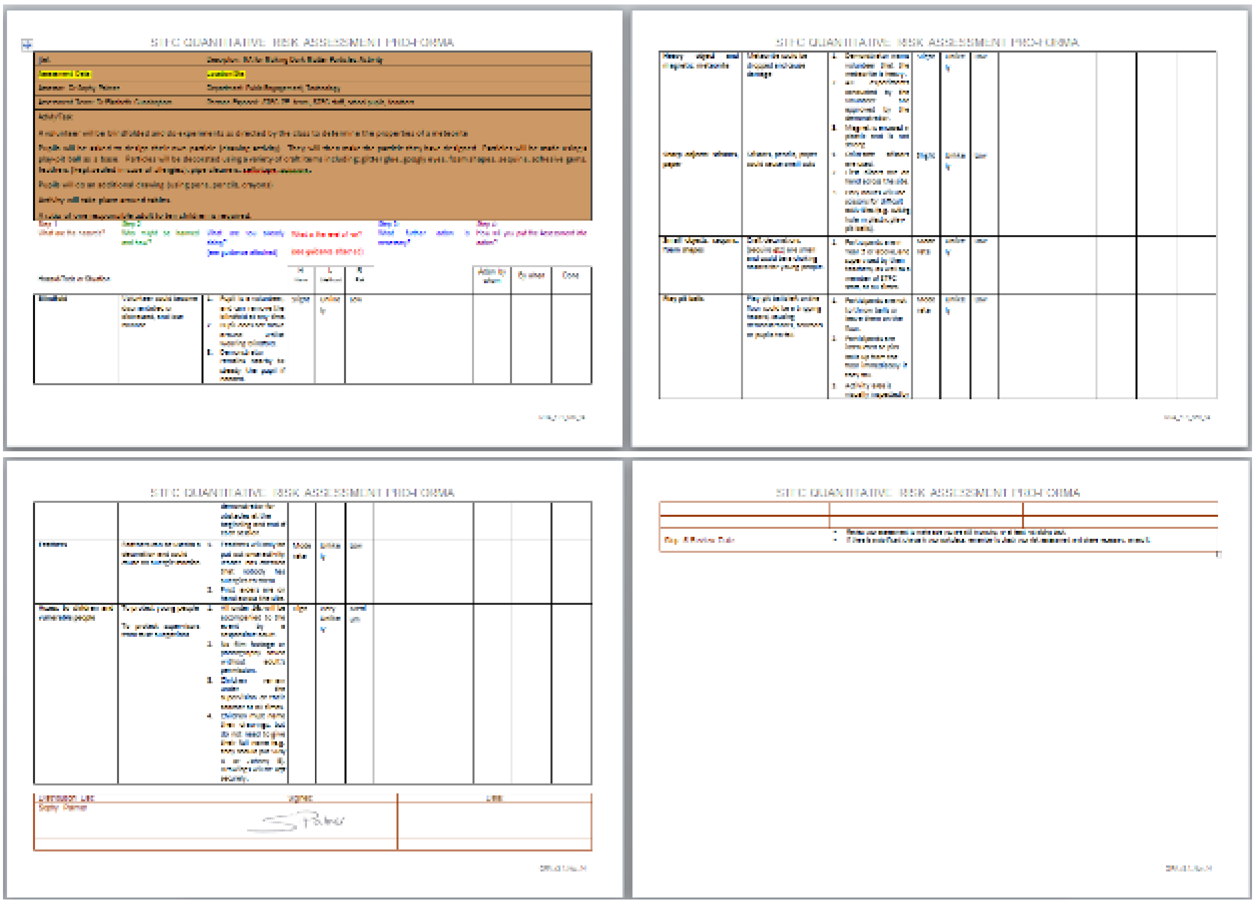
So, everyone needs to take a piece of paper and draw (using pens, pencils or crayons) what they think the most exciting thing about Boulby is. It could be dark matter, or practice for exploring other planets, or geology … Remember to write your name and school on the back of your drawing.

Recap:

- We know there's heavy stuff (dark matter) out in the Universe, which we can't see
- We can learn about it's properties even though we can't see it
- Scientists all over the world, and at Boulby Underground Laboratory, are trying to find dark matter

- Risk assessment for activity: RA_MakingDarkMatterParticles.docx

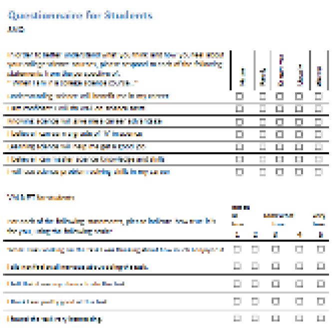
CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

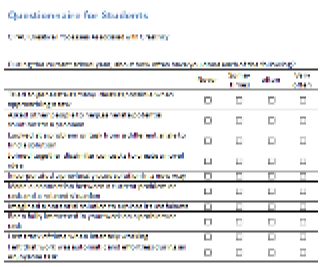


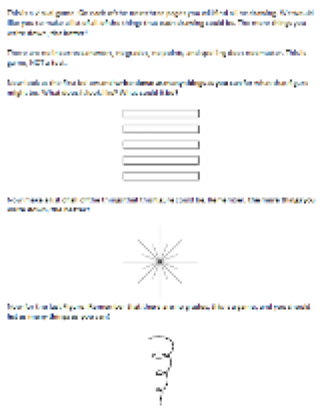
CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

- Pupils will complete a worksheet detailing the investigation of the properties of materials
  - This assessment will record the experimental methodology used by the students and establish whether the students successfully designed and carried out an investigation using scientific principles.
- Pupils will complete an artistic representation of dark matter – either the piece itself, or photographs of it, can be kept as a record for assessment.
  - This assessment will demonstrate whether the student fully engaged with the process of expressing scientific ideas and principles in an artistic and playful way.
- The CREATIONS post questionnaire will be given to students after the activity.
  - This assessment will identify the students' attitudes towards the activity, science as a career and the creative methods used.


Questionnaire for Students


Questionnaire for Students



CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

- An investigation of dark matter experiments
- Write a story or a play or a poem about the journey their dark matter particle.
- Visit a relevant science or discovery centre.

9. References

CREATIONS demonstrator: Particle Physics Workshop (University of Birmingham)

D3.2.60 Exploring Exoplanets

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Elizabeth Cunningham, Sophy Palmer
Code:	D 3.2.60.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy and astrophysics, Art

1.2 Type of Activity

In school

1.3 Duration

Minimum 45 minutes – extendable to a long-term project

1.4 Setting (formal / informal learning)

Formal learning

1.5 Effective Learning Environment

Communication of scientific ideas to audience / Arts-based

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Science in schools is often presented as a series of existing facts that were discovered many years ago. It is important that we share the excitement of science – new discoveries, unanswered questions etc. – and the need for creativity and imagination in order to engage with students and demonstrate that there is still much more to do and many areas to which they can contribute themselves.

2.2 Added Value

By exploring the topics of exoplanets and astrobiology through creating their own planets / aliens, students are able to see for themselves the imagination needed by scientists when considering and searching for other worlds or when considering other forms of life. This area of science – with its big questions and where new discoveries are being made on an almost daily basis – is ideal to demonstrate that the children can contribute to the subject themselves.

3. Learning Objectives

The solar system and the planets are included in the Key Stage 2 (age 9-11) curriculum in England, as is evolution and inheritance (how animals are adapted to their environments). This demonstrator allows children to explore and revise this topic, as well as providing important enrichment opportunities. The demonstrator also gives pupils and teachers the opportunity to cover other parts of the Key Stage 2 curriculum, including story writing, character motivation, art.

3.1 Domain specific objectives

- Children will learn about / review their knowledge of the planets in our solar system and the conditions that exist on them.
- Children will learn about the existence of exoplanets, with particular reference to the Goldilocks zone (where conditions are such that liquid water can exist).
- Children will learn about the field of astrobiology: how we look for alien lifeforms.

3.2 General skills objectives

- To understand that scientists do not know everything and there is still lots of work to do to answer the most interesting questions in science.
- That the students themselves can contribute to understanding the Universe around them.
- For the students to be able to discuss and communicate their ideas for their planets and aliens.
- For the students to be able to explain the reasoning behind their alien's development on their planet and connect it to the scientific principles of adaption.
- For the students to be able to analyse the characteristics of their alien and planet and use their ideas to develop a story.
- To develop artistic painting techniques to realise their planets and aliens – including colour mixing.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Children will take part in a series of activities related to exoplanets (planets orbiting stars other than our Sun) and astrobiology (the search for and study of the possibility of life on other planets), investigating and exploring what kinds of other planets there could be in the Universe and what kind of life could exist on them. They do this through imagining an exoplanet, creating a physical version of their planet, and producing an 'alien passport', drawing their alien, creating a story about the adventures of their alien and drawing themselves being part of the team working on the search for exoplanets and alien life.

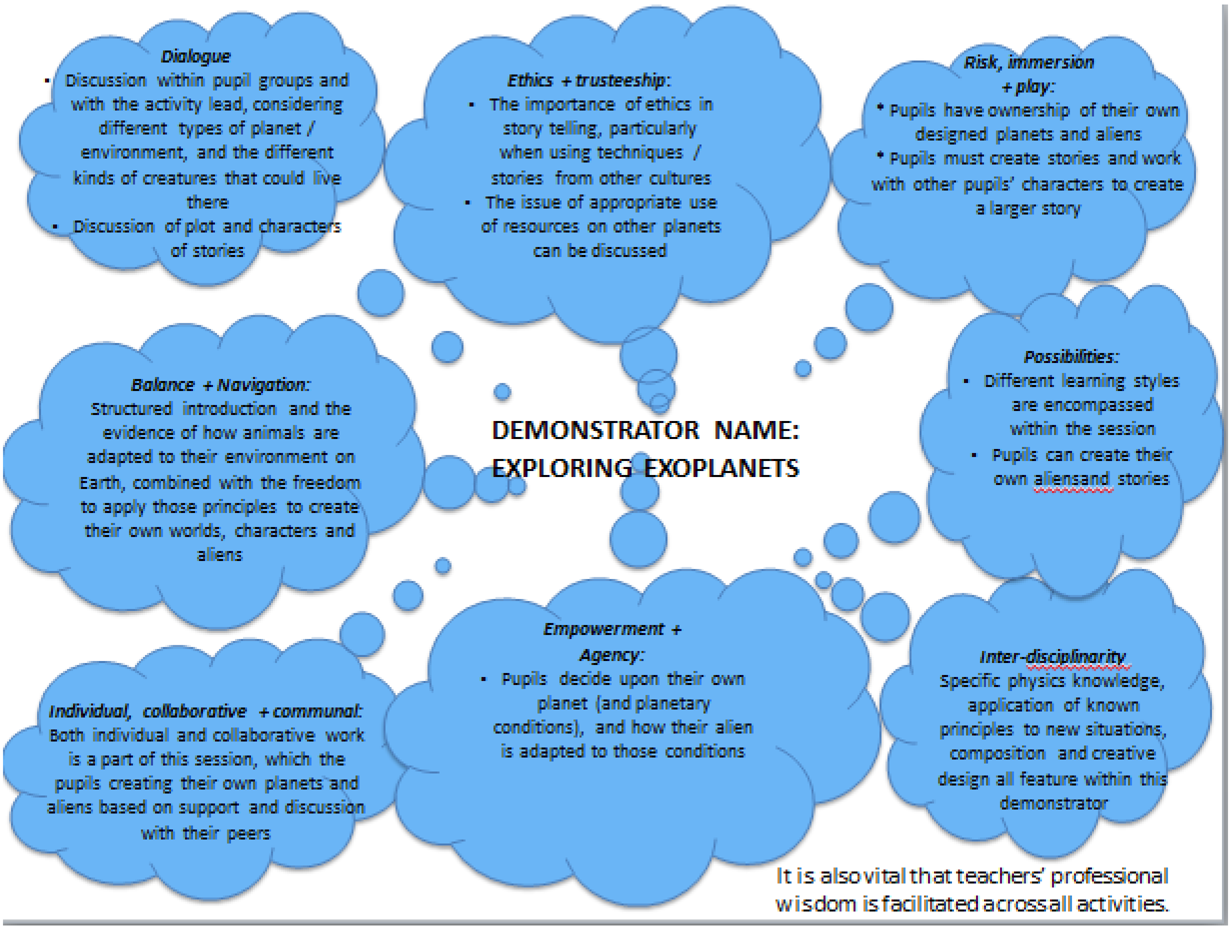
This demonstrator is intended for pupils at the upper end of primary school – ages 9-11. The demonstrator starts with the known basis of our solar system and its planets, allowing students and teachers to revise this curriculum topic, and then goes on to explore the idea of exoplanets – planets orbiting stars other than our Sun. Students not only learn about this field of astrophysics, but also must use their creativity to imagine other worlds, drawing on the techniques learnt in their art classes to create their own planet, discussing the conditions on the planet with their peers and explaining / presenting their planet to the teacher and class.

From this point, it is a natural progression to talk about the search for life on other planets – both within our Solar System and beyond. This is an excellent opportunity to bring in current, cutting-edge scientific missions and ideas, such as the ExoMars mission, part of which is orbiting Mars now, and part of which is scheduled for launch in a few years. Concepts such as the Goldilocks Zone (where it is not too cold and not too hot for liquid water to exist) are discussed, as well as the possibility of life beyond Earth. After this discussion, the pupils create an 'alien passport', for an alien living on their planet, designing a symbol for their planet (e.g. a flag) as well as drawing a picture of the alien, discussing with their peers why their alien looks the way it does (e.g. it lives on a very cold planet and so has fur), bringing in key ideas about how animals are adapted to their environments.

The class goes on to discuss how their aliens are different from us, and each student writes a story about their alien, remembering that – as they live on a different planet – their adventures will probably be different from ours. This allows the teacher to bring in / revise storytelling techniques, focusing on character motivation, which is an important part of the English Curriculum in the UK.

The class is introduced to some of the scientists and engineers who are involved in the ExoMars mission (using slides / photos available online from the ESA website among others), and there is a discussion of the different roles and skills needed in the search for alien life and the worlds on which they live. A particular focus on the often-misunderstood career of engineering is helpful here. Pupils are then invited to 'join the team', and draw themselves helping in the search for alien life.

The CREATIONS cloud demonstrates how all CREATIONS features are included in the demonstrator.



4.2 Student needs addressed

This workshop allows the pupils to act creatively, using dialogue and play to explore the possibilities of other planets, and life on other planets, in an interdisciplinary manner. The teacher will provide support for the pupils by giving them the necessary background scientific knowledge. By giving the pupils ownership of their own planets and aliens, they will be encouraged to explore the consequences of their choices (e.g. if their planet is half warm and half cold, where will their aliens live?). By asking the pupils to 'join the team' and imagine how they could help in the search for exoplanets and alien life, they will start to consider possible future careers, and will hopefully find it easier to identify with science and engineering.

5. Learning Activities & Effective Learning Environments

Science topic: Solar system, exoplanets, astrobiology, evolution/adaptation (Relevance to national curriculum) Link to and enhancement of curriculum through solar system topic and to the topic of evolution and adaptation. Class information Year Group: Year 5-6 (English school system) Age range: 9-11 Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Background information – slides** **Polystyrene 'planet' balls (~10cm diameter), or plain paper plates** **Coffee stirrers** **Paints and paintbrushes** **Printed 'alien passports'** **Printed 'join the team' worksheets** **Pens and pencils** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* Classroom *Health and Safety implications?* Risk assessment attached – regular art/craft activity. No additional risks. *Technology?* Projector *Teacher support?* Background information

Prior pupil knowledge **The demonstrator can act either as an introduction to the planets in our Solar System, or as a useful revision activity.**		
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will • Revise the planets of the Solar System • Learn about the existence of exoplanets • Create their own planet • Learn about the science of astrobiology • Create their own alien passport • Create a story for their alien • Draw themselves helping in the search for exoplanets and alien life		
Assessment • As a short activity, the short CREATIONS pre- and post-questions can be used (see below) • Painted planets, alien passports, and stories can all be kept, photographed and recorded to form part of the teacher's assessment in art / science.	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Each pupil will be encouraged to complete each task to the best of their ability. More able children will construct intricate planets, with weather patterns / buildings etc, discuss the symbol of their planet with reference to country's symbols (flags, crests etc), decide on the characteristics of their alien	**Key Concepts and Terminology** **Science terminology:** Solar system, exoplanet, astrobiology, alien, adaptation **Arts terminology:** Design, painting, drawing, storytelling

The pupils' drawings of themselves can be collected and formed into a collage of (e.g.) "Future Engineers" (see below for example)	dependent on their planet's environment and write a detailed story with complex characters. The artistic / creative activities allow space for students to express themselves differently.	

Session Objectives:

During this scenario, students will

- engage with some of the key questions about our Universe: are we alone? Is there life out there?
- consider the possibilities for their own future careers by drawing themselves helping in the search for life - as an engineer, a scientist, a safety advisor etc.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	Students will discuss exoplanets, including the conditions that could exist on them. Students will also discuss the possibility	The teacher will challenge the pupils to consider the possibilities of other planets,	Students design their own planet based on their discussions

	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	of life on other planets.	and life on other planets, both in our Solar System and beyond.	and their questioning of what type of planets and alien life are possible.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	As a class, students discuss why the planets in our Solar System look different – what is Jupiter's Red Spot, why is Mars red etc? Pupils can also return to this when discussing the evidence of how terrestrial animals are adapted to their environments.	The teacher shares information about our Solar System, exoplanets and the field of astrobiology.	Students design their own planet based on examples from our Solar System and evidence gathered from exoplanet surveys.

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students discuss the possibility of life on other planets, both in and outside of our solar system, with reference to past, current and future missions searching for life. Pupils should use examples of animals from different environments on Earth to develop the features of their alien.	The teacher questions the students, asking them if they think there is other life in our Solar System, or in the Universe.	Pupils should paint their own planet, and create an alien passport for an alien living on their planet. Their designs will be influenced by the group discussions about our Solar System and the exoplanets discovered so far.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain why their created planet has the appearance they have chosen – is it hot? stormy? etc. Students must also explain why their alien has the features it does.	Teachers should encourage pupils to challenge one another, developing new ideas for how aliens (and planets) could look.	Students explain the artistic choices for their planets and aliens based on the planetary examples they have been shown. They may take the ideas / evidence to extreme to create an interesting environment for their alien.
Phase 5:	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Pupils should draw on their knowledge of animals from differing environments on Earth to explain the	Teachers should encourage discussion of different environments	While writing stories involving their aliens, pupils can draw on their

CONNECT: students connect explanations to scientific knowledge	their evidence and explanations in relation to the original question.	appearance of their alien.	and customs that are found on Earth.	knowledge of stories from other cultures and environments.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Pupils should develop a story for their alien, paying attention to character motivation and the environment of the story.	Teachers should ensure that pupils consider the different nature of their aliens, remembering that goals may be different for different characters.	Story writing is a key skill in the language curriculum at primary school.
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Pupils should reflect on the range of planets and aliens that have been developed.	Teachers should stress the wide range of possibilities, and	Pupils should draw themselves assisting in the search for

REFLECT: students reflect on the inquiry process and their learning			use this to emphasize the need for many different people, all working together, to help in the search for exoplanets and alien life.	exoplanets, and the search for alien life.

6. Additional Information

This activity has been run several times at the STFC Rutherford Appleton Laboratory.

While students are interested to learn the hunt for exoplanets, they become much more engaged when given the opportunity to personalise their learning by creating their own planet and imagining their own aliens. They fully engage with the discussions around: 'how aliens might be different from us' and 'how the properties of their planet might affect the aliens that live there'. Pupils have been particularly interested in the concept of the Goldilocks Zone, pleased that they can apply their knowledge of a fairy tale to a scientific concept.

Students are also proud of the stories and art work they create and talk enthusiastically when explaining what they produced to their peers. Allowing the students the freedom to imagine and to create something for themselves gives them more ownership over what they have learned and allows them to have a personal impact on the outcomes of the session.

- Attached slides [ExploringExoplanets.pptx]

Who can tell me what these are?

They're our planets. Who can tell me their names? Can you tell me anything about any of the planets?

This is Jupiter, and Ganymede – Jupiter's largest moon. We think Jupiter has 67 moons.
Who can tell me what this red spot here is? It's a storm – the largest storm in the solar system. It's large enough to contain two or three Earths!

All of the planets look very different – there are rocky planets, gas giants, cold planets, hot planets, stormy planets, icy planets.

But there aren't just planets near us – there are planets all over the galaxy, orbiting lots of different stars. We've found more than 1000 planets around other stars – they're called exoplanets.

APOD 2015 May 15: https://apod.nasa.gov/apod/ap150515.html
Jupiter, Ganymede, Great Red Spot
Image Credit & Copyright: Damian Peach/SENExplanation: In this sharp snapshot, the Solar System's largest moon Ganymede poses next to Jupiter, the largest planet. Captured on March 10 with a small telescope from our fair planet Earth, the scene also includes Jupiter's Great Red Spot, the Solar System's largest storm. In fact, Ganymede is about 5,260 kilometers in diameter. That beats out all three of its other fellow Galilean satellites, along with Saturn's Moon Titan at 5,150 kilometers and Earth's own Moon at 3,480 kilometers. Though its been shrinking lately, the Great Red Spot's diameter is still around 16,500 kilometers. Jupiter, the Solar System's ruling gas giant, is about 143,000 kilometers in diameter at its equator. That's nearly 10 percent the diameter of the Sun.

You might have seen in the news, but recently we found a very special set of planets – called Trappist 1. There are 7 planets orbiting a small star quite close to us – 40 light years away. We found it using a telescope called the Spitzer Space Telescope.

The really special thing about them (CLICK) is that they're all quite like Earth!

What do you think they look like? Is there water on them do you think? We're going to try to find out. Now there are paints on your tables – choose your colours, and think about patterns. Do you want storms there? Or water?

Seven worlds orbit the ultracool dwarf star TRAPPIST-1, a mere 40 light-years away. In May 2016 astronomers using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) announced the discovery of three planets in the TRAPPIST-1 system. Just announced, additional confirmations and discoveries by the Spitzer Space Telescope and supporting ESO ground-based telescopes have increased the number of known planets to seven. The TRAPPIST-1 planets are likely all rocky and similar in size to Earth, the largest treasure trove of terrestrial planets ever detected around a single star. Because they orbit very close to their faint, tiny star they could also have regions where surface temperatures allow for the presence of liquid water, a key ingredient for life. Their tantalizing proximity to Earth makes them prime candidates for future telescopic explorations of the atmospheres of potentially habitable planets. All seven worlds appear in this artist's illustration, an imagined view from a fictionally powerful telescope near planet Earth. Planet sizes and relative positions are drawn to scale for the Spitzer observations. The system's inner planets are transiting their dim, red, nearly Jupiter-sized parent star.

What we'd like you to do now is to think about all the different ways planets can look – what could they be like? Hot or cold? Watery or icy or full of lava.

We're going to split you into groups, so you'll all do each activity. When you're painting planets, you need to write your name on a wooden stick, take a planet sphere and put your stick into the planet sphere, and then use the paints to paint a beautiful planet! Talk in your groups about why your planet looks the way it does!

This is Saturn – with the beautiful rings. This was taken by a spacecraft called Cassini – this year Cassini is going to dip in and out of Saturn's rings and then crash into Saturn.

Can anybody see me this tiny dot, here? Can anybody tell me what it is? It's Earth.

Now, there's life on Earth – but do you think there might be life on other planets too? Or other moons?

APOD 2006 October 16 : https://apod.nasa.gov/apod/ap061016.html
In the Shadow of Saturn
Credit: CICLOPS, JPL, ESA, NASA **Explanation:** In the shadow of Saturn, unexpected wonders appear. The robotic Cassini spacecraft now orbiting Saturn recently drifted in giant planet's shadow for about 12 hours and looked back toward the eclipsed Sun. Cassini saw a view unlike any other. First, the night side of Saturn is seen to be partly lit by light reflected from its own majestic ring system. Next, the rings themselves appear dark when silhouetted against Saturn, but quite bright when viewed away from Saturn and slightly scattering sunlight, in the above exaggerated color image. Saturn's rings light up so much that new rings were discovered, although they are hard to see in the above image. Visible in spectacular detail, however, is Saturn's E ring, the ring created by the newly discovered ice fountains of the moon Enceladus, and the outermost ring visible above. Far in the distance, visible on the image left just above the bright main rings, is the almost ignorable pale blue dot of Earth.

Now, if there are aliens – like us – where might they live? What would they look like? Would they have eyes and hands and mouths?

We'd like you to make an alien passport. On the front, draw a symbol of your planet – it could be a flag. Inside your passport, draw a picture of your alien. It's address is how many planets away from the sun it lives.

So maybe, a long way away, there are aliens a bit like us. But what about closer to home?

We're trying to find out! This is a picture of what a mission called ExoMars. ExoMars is going to Mars soon and it's going to look for signs that, long ago, there was alien life there.

Does anybody think there could be life – probably little squiggly life – in our solar system?

Lots of different people are involved with searching for other planets, and searching for alien life.

This is the ExoMars team – they've got lots and lots of different people, all helping. Some, like Pia, help with the computers – and Silvia is a systems engineer, she makes sure that everything works properly together. This is Chris, and he's in a mine – one of our labs, in Yorkshire, is helping scientists figure out how to look for the signs of life, and testing the robots we'll send out into space. Albert, up here, is the engineer in charge of testing everything for ExoMars, and this is Sarah – she works here, and she's the engineer who is in charge of what we're doing to help ExoMars.

Now, I talked about engineers quite a lot. Who can tell me what an engineer is?
Well, we think engineers are a bit like bees.

BOTTOM LEFT: ESA team: http://exploration.esa.int/mars/56724-the-esa-exomars-team/
TOP LEFT: Pia Mitschdoerfer: ExoMars Mission & Software Systems Engineer
http://exploration.esa.int/mars/49807-an-interview-with-pia-mitschdoerfer/
TOP SECOND LEFT: Silvia Bayon: ExoMars Spacecraft Composite Systems Engineer
http://exploration.esa.int/mars/49747-an-interview-with-silvia-bayon/
TOP RIGHT: Albert Haldemann: ExoMars Payload and AIV Manager
http://exploration.esa.int/mars/46714-an-interview-with-albert-haldemann/
BOTTOM RIGHT: Sarah Beardsley: Head of Space Engineering and Technology, RAL Space
TOP SECOND RIGHT: Chris Toth, Boulby

CREDIT NOTE: Illustrations by Helen Towrie www.helentowrie.com

You see the product of bees everywhere. You can buy it easily in almost any shop

Just like you see the product of engineers everywhere (everything in picture in manmade)

But, you don't often see bees because there aren't many of them – even though bees are super important!

Engineers are the same. There aren't many of them...

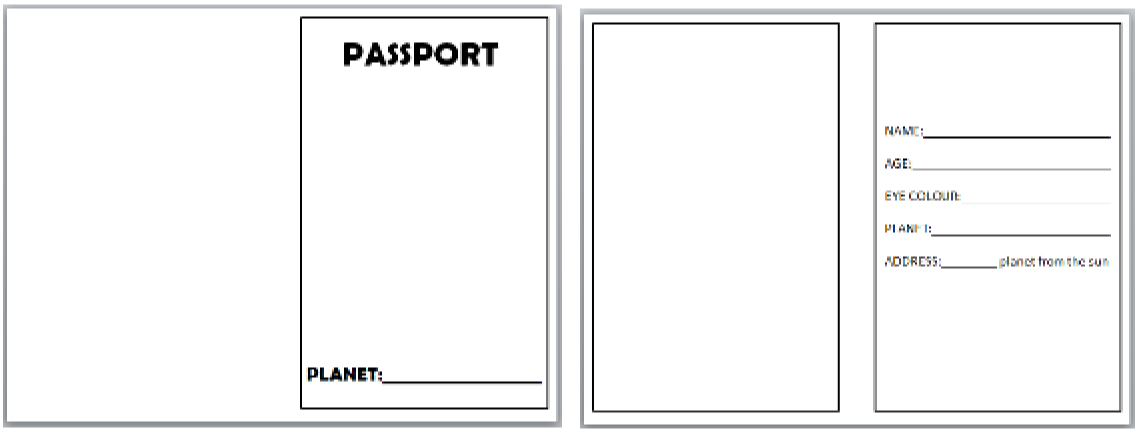
CREATIONS has received funding from the European Commission HORIZON2020 Programme

even though they make everything.

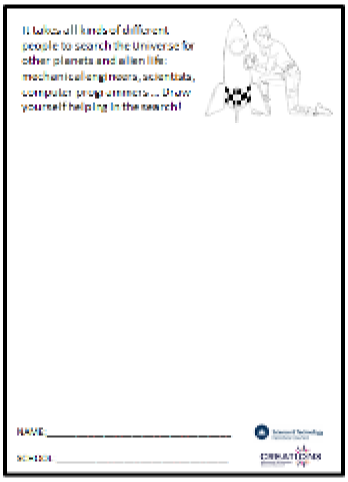
So because there aren't many of us, we need help, so we'd like you to join the team!

This is Helen's drawing, of what she thinks she'd like to do to help find other planets, and life on other planets. We'd like you draw us a picture of yourself, helping with the search. What do you think you would like to be?

- Attached alien passport template [AlienPassport.pptx]

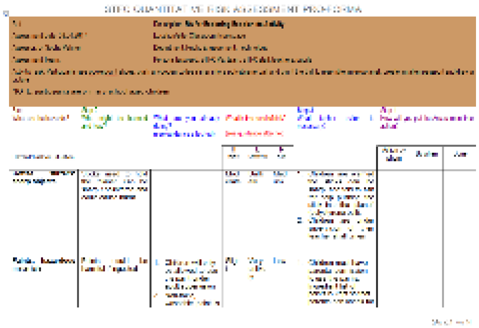


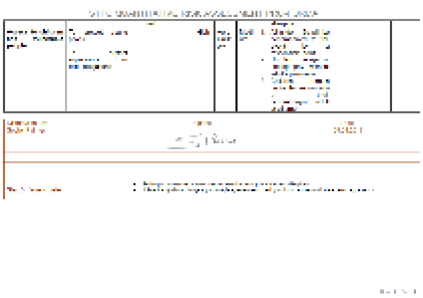
- Attached "Draw Yourself" worksheet [DrawYourself.pptx]



- Example collage of "Future Engineers"

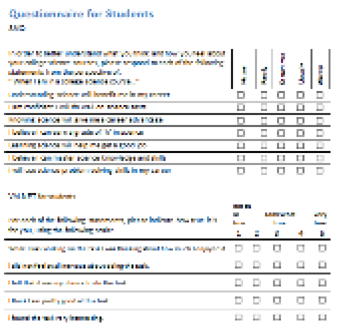
- Attached risk assessment for activity [RA_ExploringExoplanets.docx]

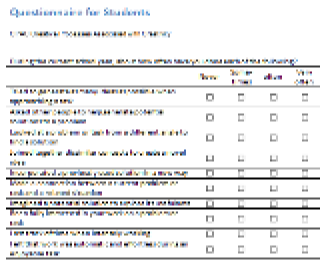


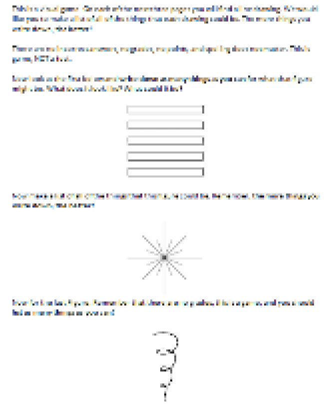


7. Assessment

- Pupils will create a planet, an alien passport, write a story, draw themselves, and present their work. Photographs of the planet should be taken as assessment evidence (to allow the pupils to keep their own planets).
    - This assessment of these outputs will show how the students engaged with the session and whether they understood the scientific principles explained to them during the session.
- The CREATIONS post questionnaire will be given to students after the activity:
    - This assessment will identify the students' attitudes towards the activity, science as a career and the creative methods used.


Questionnaire for Students


Questionnaire for Students



CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

There are many potential extensions to this project:

- Pupils can do a project about a planet or a moon in our Solar System, learning about the possibilities of life on that planet. The NASA webpages are a good place to find information.
- Pupils can make a model or puppet of their alien.
- Pupils can develop and perform a play involving their aliens, involving aliens and planets created by different pupils.
- Pupils can research extremophiles – animals which live in extreme environments on Earth.
- Pupils can discuss the natural resources on their planets, and use the activities to talk about green issues.
- Visit a relevant science or discovery centre.
- Follow up online investigations:
    - using exoplanet counters e.g. https://exoplanetarchive.ipac.caltech.edu/
    - citizen science e.g. https://www.planethunters.org/

9. References

- ESA ExoMars page: http://www.esa.int/Our_Activities/Space_Science/ExoMars
- NASA Exoplanets page: https://exoplanets.nasa.gov/
- NASA Solar System page: https://solarsystem.nasa.gov/planets/
- Cassini mission page: https://www.nasa.gov/mission_pages/cassini/main/index.html

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.61 Shadow Puppets

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Sophy Palmer, Elizabeth Cunningham
Code:	D 3.2.61.	**Contributors:**	
Version & Date:	V1, 06.02.2017	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Theatre education

1.2 Type of Activity

Investigation, performance, classroom-based

1.3 Duration

Variable:

- Introduction (including slides, role play): 30 minutes
- Investigation (min 30 min, extendable)
- (Optional): Composition of play (min 30 min, extendable)
- Creation of shadow puppets (min 15 min, extendable)
- Performance

1.4 Setting (formal / informal learning)

Formal learning (classroom setting)

1.5 Effective Learning Environment

- Experimentation
- Arts-based

2. Rational of the Activity / Educational Approach

2.1 Challenge

(Description of the problem)

Shadows and their effects feature in key parts of the science curriculum at primary level in the UK. Despite the importance of this topic many primary teachers find it challenging to teach these subjects to their students in an engaging way, particularly those teachers without a science background. When teachers lack confidence in their teaching of a particular subject area student's knowledge of these areas also suffers. This is a critical issue for students in the UK where shadows and their effects form such an important part of the curriculum.

Through the Shadow Puppets workshop, teachers can use the topic of shadows to introduce concepts such as: the phases of the Moon, eclipses and sundials. This workshop also opens up the scientific topic of shadows to include creative and artistic aspects, inspiring students understanding, while allowing students to engage creatively with shadows and explore for themselves the effects of shadows in space and on the Earth.

This workshop provides the framework to improve teacher confidence in teaching shadows and their effects, while enabling students the freedom to grow their understanding of this important topic.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

Pupils will apply knowledge that they discovered for themselves in a creative and artistic scenario. By using both scientific and artistic thought processes pupils will gain hands-on experience of creating craters and apply the 'analyse', 'explain' and 'communicate' phases of the IBSE cycle. It will also allow primary school teachers to run a cross-curricula lesson, incorporating elements from the science, literacy and art curricula.

Throughout the investigation, pupils will explore the scientific method and must be self-critical of their approach to make sure they investigate different variables in a consistent and scientific way. By then applying their self-obtained knowledge to the creation of an artwork they will gain ownership of it, exploring through play the concepts they have found and their own understanding.

3. Learning Objectives

3.1 Domain specific objectives

The shadow puppet demonstrator will allow pupils to create both a scientific report of their observations, and a performance (this can be recorded in terms of a script, photographs and videos of the performance if desired and as appropriate).

Pupils will learn about shadows, and how to conduct a scientific investigation (including recognising and controlling variables, taking measurements, recording data, making predictions, presenting results). The investigation will include topics including shadows and space. Pupils will also cover the art curriculum (England) learning objective of using various techniques to create art, and the literacy learning objectives relating to composition.

If desired, the demonstrator can be extended to discuss the use of shadow puppets, historically and in the modern era, in different cultures.

3.2 General skills objectives

- To develop teamworking skills through investigation and collaborative creation.
- To understand scientific concepts through conducting an investigation.
- To apply scientific concepts together with composition skills to create a story and performance piece.
- To develop the ability and skills to conduct a scientific inquiry, identifying the questions and concepts needed to guide their investigations.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Primary school pupils must learn how to conduct scientific investigations and apply their findings to the world.

Over the course of the demonstrator, pupils must conduct an investigation in how shadows are formed – studying the angle of the light source, the distance between the object casting the shadow and the light source, and the distance between the object casting the shadow and the screen.

Once the investigation is concluded, pupils work in teams to create a shadow puppet show, using the conclusions they reached during the investigation to tell a story (i.e. making the rocket get bigger / smaller as required by the story).

The final aim of the demonstrator is to motivate pupils who are not typically engaged with science by allowing them to use their own conclusions in order to create a story and performance in a lively and unusual fashion.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4.2 Student needs addressed

Students work in teams to conduct the investigation, reach conclusions, design their artwork and agree on how to achieve their goals. They are supported by a worksheet (see section 6) to help with the investigation and by the activity lead posing key questions (e.g. how are they making it a fair test).

This demonstrator enables to pupils to engage in collaborative discourse, building constructively upon one another's ideas – both during the scientific investigation of how shadows form, and during the creation of a shadow puppet play. During the investigation phase, pupils apply IBSE-based approaches (as scientists do) in order to address a scientific question. The demonstrator allows pupils to express themselves creatively and apply the knowledge they have obtained in an artistic fashion.

5. Learning Activities & Effective Learning Environments

Science topic: Light and Shadow (Relevance to national curriculum) This topic links directly to the English Curriculum in Science and English Language Class information Year Group: England Year 5-6 Age range: 9-11 years old Sex: both Pupil Ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • Scissors • Sellotape • Printed shadow puppet templates (optional) • Kebab sticks or straws • Lamp or torch • Roll of baking paper • Different sized balls (to represent the Sun, the Moon and the Earth) *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* Classroom space *Health and Safety implications?* • Some sharp objects (kebab sticks, scissors) are used: pupils must be careful and teachers / demonstrators vigilant • It is important that the teacher / demonstrator stresses that children should NEVER look at the sun, even when wearing dark glasses *Technology?* *Teacher support?* Reference material, slides
Prior pupil knowledge None required	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

- Understand that shadows are formed when light from a light source is blocked by a solid object
- Understand that eclipses happen when the moon blocks the light from the sun, and that this happens for other planets orbiting other stars
- Investigate how the size of a shadow changes in different conditions
- Compose a play / story (including planning, drafting, evaluating, editing)
- Perform their composition

Assessment	**Differentiation**	**Key Concepts and Terminology**
• Students will conduct an investigation, which should be written up for evaluation • Students should write their story for assessment • Students will perform their story using shadow puppets	*How can the activities be adapted to the needs of individual pupils?* All pupils have the same objective – to understand how the size of shadows changes. More able pupils should investigate a greater number and variety of variables. All pupils will compose a shadow puppet play, but this can be more complex to suit the ability of the individual pupil. The artistic outcome of this demonstrator allows pupils to express themselves differently.	**Science terminology:** 1. Shadow, light, size, eclipse **Arts terminology:** • Shadow puppet, play, compose

Session Objectives:

During this scenario, students will

- Learn the cause of eclipses
- Investigate how the size of shadows change
- Compose a play
- Perform the play with shadow puppets, using the knowledge they have gained to create appropriate sized shadows

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity*	Eclipses are discussed, and pupils investigate how shadows are formed – specifically how to make shadows smaller and larger.	Teachers / Demonstrators will discuss eclipses with the class, and work with them to investigate the formation of	Pupils should make their own shadow puppets in order to investigate the

	and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.		shadows. Teachers / demonstrators will discuss the importance of a fair test with the class.	patterns shadows make.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will collect data on how shadows are formed by investigating it, defining variables and recording data.	Teachers / demonstrators will lead the investigation, stressing the importance of accurate measurement taking and recording of data.	Students will think about how they could use their data to further a story plot line, discussing ideas for their plays.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will analyse their data and draw conclusions together.		
Phase 4:	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students will discuss the possible physical principles behind their conclusions.	Teachers / demonstrators will support the class discussion, ensuring that	Teachers and pupils will discuss how they could use these physical

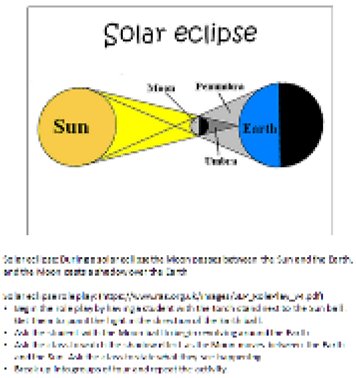
EXPLAIN: students formulate an explanation based on evidence			accurate conclusions are drawn.	principles to create a character or story plot.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students will connect their investigations into how shadows are formed and what affects their size to the use of shadows in science e.g. discovering exoplanets.	The teacher will lead a class discussion about how their investigations relate to eclipses, and the discovery of exoplanets.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Pupils will discuss their investigation, results and conclusion with their peers.	Teachers should ensure that the discussion includes key points – including reinforcing how we can create and control shadows, and the methodology the pupils followed to	Pupils will compose and perform a shadow puppet play, using the knowledge they gained through investigation to create shadows as appropriate. Pupils will design and

			make their conclusions.	make their own shadow puppets for their plays.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Pupils discuss what else they could do to improve their investigation, results and conclusions.	The teacher leads a discussion on the investigation, including ideas on how to improve it in the future.	Pupils will reflect on their shadow puppet plays, and those of their peers, discussing how to improve the story, characters and staging.

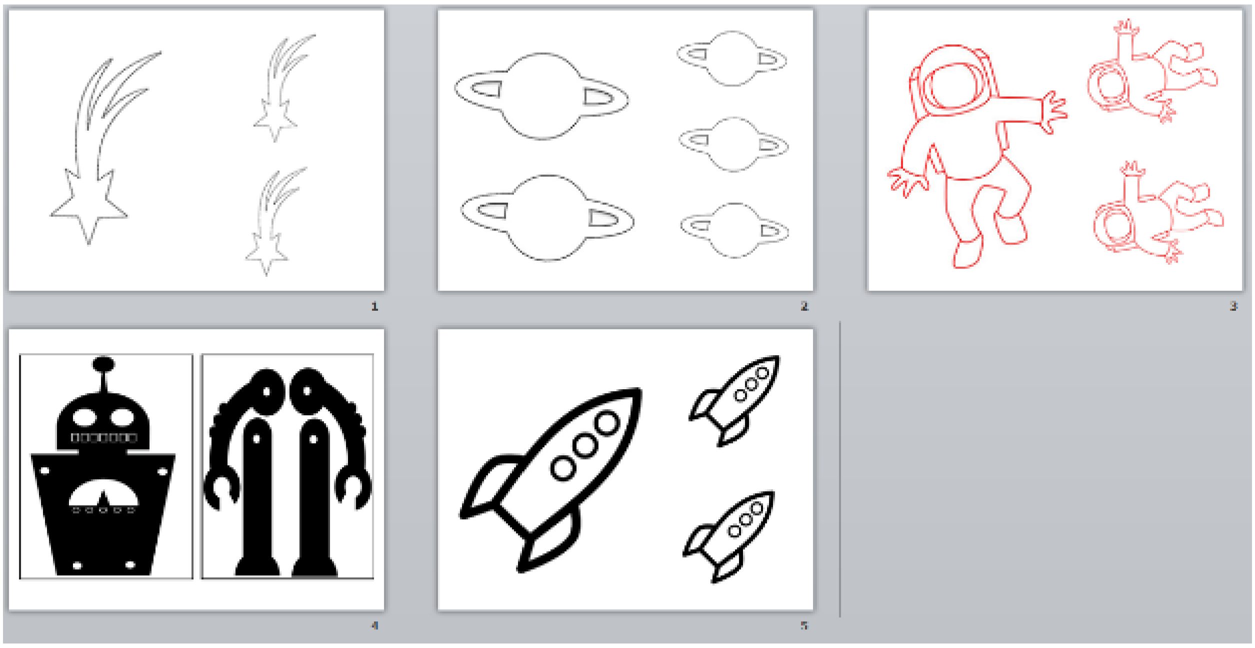
6. Additional Information

This demonstrator has been run a number of times at Rutherford Appleton Laboratory to school groups, as well as at a local community centre to mixed-age family groups. The children are enthusiastic about creating shadows, and many remember the recent near-total eclipse in the UK, giving context to their learning. The children are very proud of their shadow puppets, and enter fully into discussions of how to create the effects they want in their plays. The demonstrator is easy to differentiate, and the participants quickly grasp the concepts and principles, through a playful exploration of shadows.

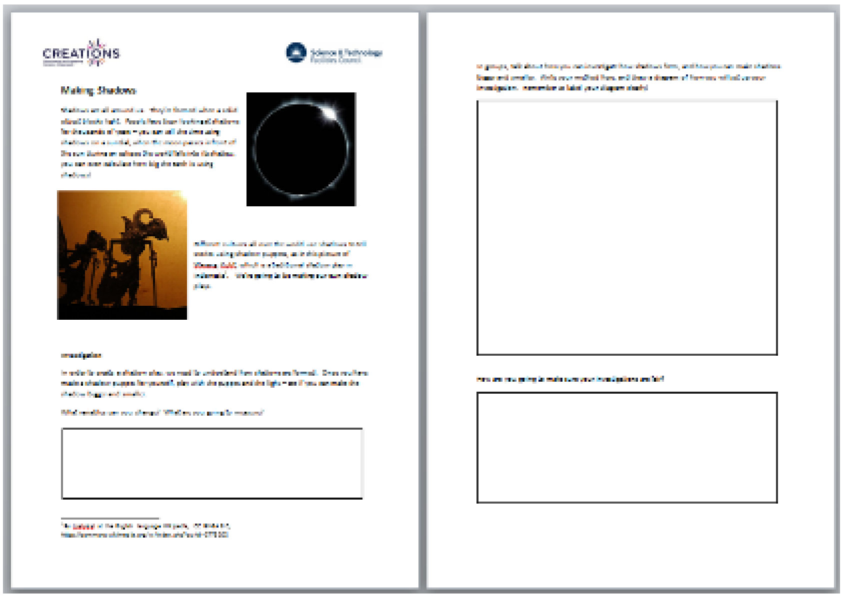
- Shadow puppets: introductory slides

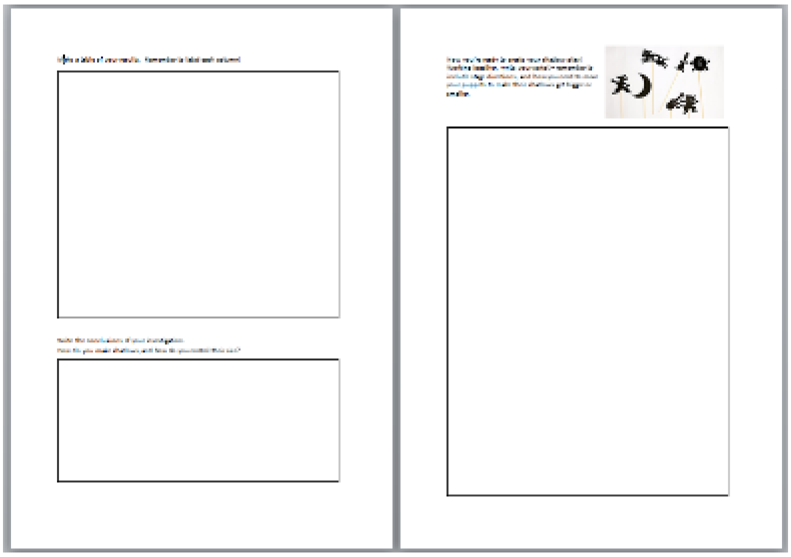


- Shadow puppets: space templates

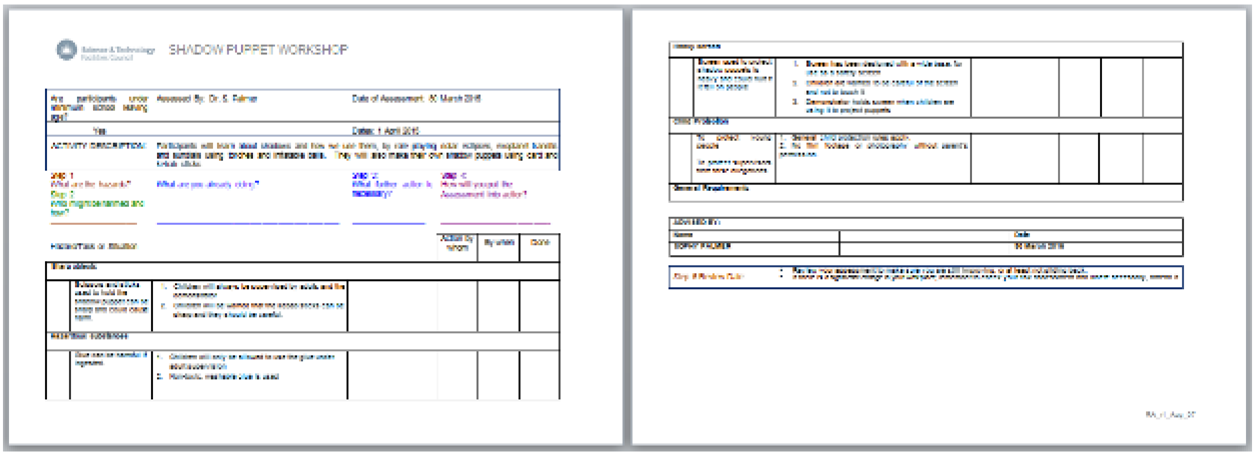


- Shadow puppets: worksheet [ShadowPuppets-worksheet.docx]



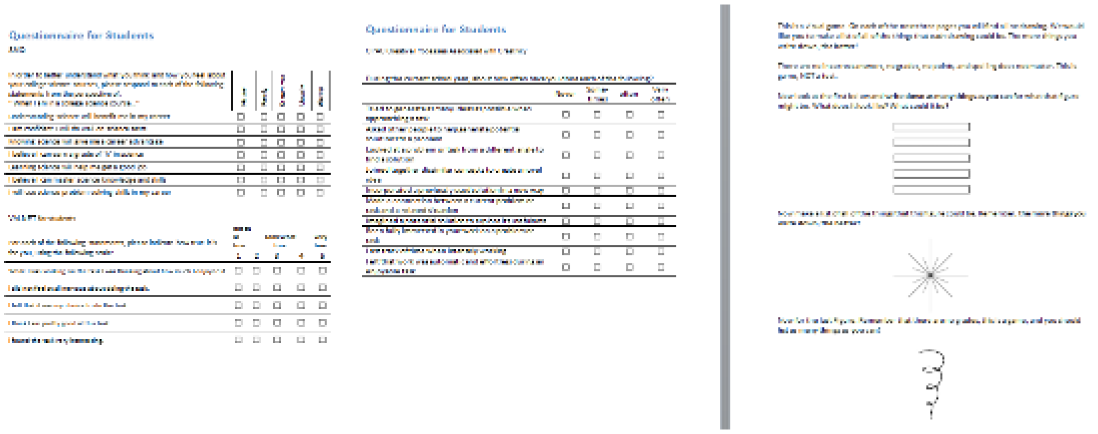


- Shadow puppets: risk assessment



7. Assessment

- Pupils will complete an investigation report, which can be kept by the teacher as a record of their achievements.
  - This assessment will record the experimental methodology used by the students and establish whether the students successfully designed and carried out an investigation using scientific principles.
- Pupils will compose and perform a shadow puppet play – either the play itself (the script), the shadow puppets themselves or photographs / videos of the play, can be kept as a record for assessment.
  - This assessment will demonstrate whether the student fully engaged with the process of expressing scientific ideas and principles in an artistic and playful way.
- The CREATIONS evaluation framework will be applied by giving students the CREATIONS post questionnaire:
  - This assessment will identify the students' attitudes towards the activity, science as a career and the creative methods used.



CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

- Pupils can complete an investigation, report and presentation about the use of shadow puppets in other cultures, both historically and in modern times.
- Pupils can investigate Erastothenes.
- Pupils can calculate the size of objects based on their shadows, bringing in mathematics.
- Pupils can visit a research centre that is involved with astronomy.
- Students can create eclipse simulations on the computer.

9. References

- National Curriculum (England), Programme of Study: Science, English
- Royal Astronomical Society, Solar Eclipse Role Play: https://www.ras.org.uk/images/SEP_RolePlay_v4.pdf

D3.2.62 Serendipity –Accidental Discoveries in Science

Project Reference:	H2020-SEAC-2014-1 , 665917	**Authors:**	Hannu Salmi Kauko Komulainen
Code:	D 3.2.62.	**Contributors:**	
Version & Date: 11.5.2016	**30/5/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Serendipity. Accidental Discoveries in Science !

Learning science by drama pedagogy.

The topic is mainly science, technology, engineering, and mathematics, which is taught by using also supporting method of art/skills education with drama pedagogy tools.

1.2 Type of Activity

Bridging the gap between formal education and informal learning via teacher professional development (TPD).

1.3 Duration

In the University of Helsinki; Department of Teacher Education; Autumn 2016 – Spring 2018

3 p. (StandardStudyCreditPoint) course containing 1) theory, 2) basic drama training; 3) lectures of public understanding of science; 4) integrative education (science; history; art; technology-handicrafts; media; mother language; 5) practicing at school; 6) Play (drama) presented; and 7) Introduction to scientific empirical thinking by the "Serendipity" phenomenon.

1.4 Setting (formal / informal learning)

Out-of-school – Open learning environments – Drama – Books – Hands-on –science – web-based materials – History of science - Demonstrations

1.5 Effective Learning Environment

Open learning environment both out-of-school and restructured classroom settings.

2. Rational of the Activity / Educational Approach

2.1 Challenge

(Description of the problem)

“Serendipity” is the term discovered by Sir Horace Whalpole in 1700s. The term has received a renessance in 2000s.

However, the scientific discoveries are not done by coincidence. “Only well prepared minds can make serendipitious discoveries”, said already Pasteur.

Scientific phenomena are mainly abstract and don’t have direct link to pupils everyday life.

On the other side, drama education is most often getting its topics from artistic topics, social matters, and psychology.

It is also essential to stay in the facts. Very often the drama or fiction is also giving scientifically wrongly expressed content. Here, the artistic approach may not lead into misconceptions.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The new Curriculum 2016 in Finland is underlining besides the subject based education also the phenomenon based education, learning and teaching.

The “phenomena”, however, are often very loosely described topics combining a variety of facts.

That’s why this Demonstrator will concentrate into very clear and reduced topic or phenomenon which can be clearly defined, and then to use drama education as a tool from STEM to STEAM.

“Serendipity” forms a link 1) between formal education and informal learning; 2) history and modern science; 3) theory and practice; 4) hard work and creativity; 5) skills and art.

3. Learning Objectives

3.1 Domain specific objectives

With the background materials like the classical book by Royston Roberts (*Serendipity. Accidental discoveries in science*) both in-service teachers and teacher students will receive deep background information and theories related to scientific process.

Thus, the teachers can select by themselves the explicit topic like Big bang, antibiotics, archelogy, vaccination, dynamite, nylon, etc. It can be found easily from this book and other available background material related to public understanding of science in web, newspapers and other sources.

This approach will also bring in the elements of RRI (Responsible Research and Innovation) to the teaching process.

3.2 General skills objectives

The main idea is to teach the scientific process and empirical research. The classical, big historical discoveries in science from Aristoteles to Newton and Pasteur to Alexander Fleming, or x-rays to DNA, will give the inspiring starting point.

This is supported by the creative elements related to serendipity. The artistic element will have an input via drama pedagogy.

However, real hands-on experiments are included to the drama pedagogy approach. The background consists of evidence-based education repeating the empirical research model with the educational 5E-model.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

4.2 Student needs addressed

5. Learning Activities & Effective Learning Environments

Science topic: **(Relevance to national curriculum)** **Class information** **Year Group:** **Age range:** **Sex: both** **Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** ***Health and Safety implications?*** ***Technology?*** ***Teacher support?***
Prior pupil knowledge	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **During this scenario, students will**	

Assessment	Differentiation *How can the activities be adapted to the needs of individual pupils?*	Key Concepts and Terminology **Science terminology:** **Arts terminology:**

Session Objectives:
During this scenario, students will

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore evolution.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in ….	
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.			

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.			
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.		
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.		.	
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			

6. Additional Information

7. Assessment

8. Possible Extension

9. References

D3.2.63 "Art of Math Exhibition"

Project Reference:	H2020-SEAC-2014-1, 665917	**Author:**	Hannu Salmi, Helena Thuneberg
Code:	D 3.2.63	**Contributors:**	
Version & Date:	**V2**	**Approved by: NKUA**	

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics, Art, Science

1.2 Type of Activity

Informal – Out-of-school Large scale National Activities

1.3 Duration

5 months

1.4 Setting (formal / informal learning)

Formal and informal. Exhibition is bridging the gap between formal education and informal learning. Interdisciplinary STEAM Pre- and Post-activities in the classroom before and after the exhibition visit support the process.

1.5 Effective Learning Environment

- Visits to exhibition research centres (virtual/physical)
- Communication of scientific ideas to audience
- Communities of practice
- Arts-based
- Dialogic Space / argumentation
- Ethics

2 Rational of the Activity / Educational Approach

2.1 *Challenge*

Learning of mathematics most often happens unconsciously. This is typically informal learning [2], which can also be utilized in a science exhibition context [3]. However, the older the children become the more complicated the mathematical problems they encounter in everyday situations and especially when they start school. Then it becomes crucial to exploit childrens'natural curiosity, imagination, and willingness to play in the learning of mathematics and to support them to discover the meaningfulness and worth of mathematics. According to the TIMSS 2015–study (TIMMS= Trends in International Mathematics and Science Study), half of the international fourth grade Mathematics curricula include attitudes and mention, for example, beliefs, confidence, and perseverance as well as the beauty of mathematics, developing a productive disposition toward mathematics, appreciating the practical applications of mathematics in life, and displaying a constructively critical attitude toward mathematics [4]. Some countries mention appreciation of scientific inquiry and science as a discipline or a curiosity and interest.

2.2 Added Value

In this Demonstrator, mathematical problem solving was combined with art. The learning context is a ***Art of Math Exhibition***, and the mix of math learning and art was represented in the building of mathematical geometric models with concrete materials. These activities require visual imagery and mental rotation. According to Hope [19], the capacity and skill to create visual representations of the mental images form an essential part of the learning process. Although the immediate goal was to enhance math learning, these activities support the development of spatial skills [20] and spatial intelligence, which have been identified as important factors of school achievement in general [21].

According to Fenyvesi, Koskimaa, and Lavicza [22] problem-solving can also be a basis for the integration of learning mathematics in transdisciplinary educational frameworks, such as STEAM-integration, although the integration of liberal arts into STEM is mutually reshaping scientific education and humanities education [23]. It seems evident that just like mathematics learning, it is recommended that science, technology, engineering, and arts education also follow problem-oriented approaches.

As the creative element and aesthetic component are the inherent core of art, combining art with math learning offers an additional dimension for concretizising math concepts. Art and math have been considered to share many principles, for example space and shape [24], but also that of aesthetics, as Mack [25] discusses in his article "A Deweyan perspective on aesthetic in mathematics education". The synthesis of math and art might show the beauty of both

domains and possibly in a novel light. As such, by applying art ways of looking and observing become critical [26, 27, 28].

3 Learning Objectives

3.1 Domain specific objectives

The main objective of the ***Art of Math Exhibition*** is to give to the **high school pupils (average age 11-13 years) an opportunity to use hands-on creative mathematical exhibits and interactive mathematical structures as cooperative group work to learn scientific, technological and engineering concepts by using art and handicraft exhibit demonstrators.**

Art of Math Exhibition domain specific objectives are to:

- Get students motivated in mathematics and STEM through Art orientated exhibition
- Teach pupils how to explore a mathematical structure with aesthetic aspects
- Initiate the development of *learning by doing*, regarding a visual mathematical topic
- Initiate contact between students and other professionals (for example university mathematians, science centre experts, and artists)
- Bridging the gap between formal education and informal learning
- Engage parents and the general public into out-of-school happenings and events
- Build National-wide pupils networks
- Open the school to the community and involve all the stakeholders.

Connecting to these main objectives, peripheral aims are formed addressing pupils' needs to:

- develop art abilities necessary to do mathematical and STEM inquiry
- develop encourage for scientific testing
- identify questions and concepts for empirical exploring in exhibition context
- design and conduct relevant and pragmatic solutions to scientific concepts and issues
- use technology to improve investigations, communications and the development of simple engineering solutions
- show the cooperative nature of scientific research as group work in an open learning environment

- learning to find information independently from the combination of exhibits
- creativity and imagination as starting point for formulating hypothesis
- recognize, analyze and imagine alternative explanations and models
- communicate a scientific argument or issue in a creative way
- develop lifelong learning skills
- taking into account the ethics, sustainability and responsible research
- link with science and society in a personal context

3.2 *General skills objectives*

In the context of the ***Art of Math Exhibition***, students' general skills objectives are:

- Hands-on activities with learning by doing -principle
- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of mathematical concepts and phenomena
- Scientific interconnection of mathematics, engineering, technology and science science with aspects of art (students will create a multidisciplinary STEM construction with clear artistic approach with hands-on workshop, which demonstrates and deepens understanding, supporting discipline knowledge in both the STEM and Arts & Skills educational disciplines).
- Develop spirit of cooperation and teamwork while exploring together the Exhibition
- Connect the science classroom with professionals and local communities
- Bridging the gap between formal education and informal learning

More Specifically:

- Pupils will learn by the Exhibition hands-on solutions about scientific concepts related to the curriculum of their courses with adding from informal learning sources
- Pupils will become involved and acquainted with the concept of learning mathematics creatively via ***Art of Math Exhibition***. Art & Skills are related to traditional STEM will lead them to "learning by doing" process and deepen their multi-discipline knowledge.
- Creative element is underlined in the open learning environment with structured goals. Pupils should also be specific about key concepts they will be focusing on.

- In the Exhibition pupils will deal with mathematical knowledge and experience with group-work in which scientific models and figures can be of great inspiration to Engineering and Tech via Art
- The students should be able to describe fundamental concepts concerning their chosen topic.
- Combining math learning with experimentation and art in a concrete model in the exhibition creates a many-sided and versatile approach.

4 Demonstrator characteristics and Needs of Students

4.1 *Aim of the demonstrator*

The demonstrator's main aim is to give the opportunity to high school students aged from 11 to 13 years old to combine math learning with experimentation and art in a concrete testng process in the exhibition as a many-sided and versatile approach. In this open learning environment of ***Art of Math Exhibition*** pupils in learn effectively by hands-on method. In this way, students learn aesthetic mathematics and science in a creative way by art and skills.

The context of the ***Art of Math Exhibition*** is a modern, mobile, and interactive exhibition. The exhibition consisted of eleven interactive, "hands-on" science exhibition objects, which the students were allowed to use, test, explore, and learn freely during a 45-minute time period. Following that they attended a workshop (also 45 minutes) in which they were allowed to build their own structures and creatures by using and applying the small "lego" type of plastic pipes and circles.

The participants in Math and Art exhibition were 11 to 13 years old from several areas, villages, towns and cities in Finland (N=556), gender equally 52% girls and 48% boys.

At least one teacher is responsible for each school/participation with the support of the science centre pedagogist and the exhibition guide. The new National Curriculum of Finland demands the teacher to use Phenomenon Based Learning (PBL). Students and teachers select a science theme that would like to develop as a STEAM-project. In this way, it is given the opportunity to pupils to inquire about mathematical, technological, engineering, and scientific concepts and issues of their interest and express their findings in creative ways.

4.2 *Student needs addressed*

The ***Art of Math Exhibition*** demonstrator offers the opportunity for the enhancement of the pupils' cognitive involvement, their representation of scientific content using their interactive cognitive processes, the pupils' hands-on involvement using the hands-on exbibits. As an open learning environment, the ***Art of Math Exhibition*** underlines the cooperative exploring with emotional involvement. Learning as group work advances the social interaction and

communication. Teachers, science centre experts, guides, artists, parents, and other adults have a tutorial supportive role in the learning process.

Situation motivation's role is essential in change of attitudes towards mathematics, science and technology and future educational plans. According the research literature ituation motivation was the most powerful explainer especially in regard to the experienced Exhibition influences on science and technology attitudes, and it also affected future educational plans. These results imply increased meta-cognition, the awareness of what one thinks and plans, like Lai, Zhu, Chen, and Li [15, p.2] observed: "Motivation is an important energizing factor of metacognition and can activate the self-regulation process". Situation motivation is boosted by relative autonomy experience.

The central aim underlying ***Art of Math Exhibition*** demonstrator educational methodology [37] is to activate pupils' familiarity with concrete, clear, aesthetic geometric structures within the context of problem-solving. This method is based upon the creative exploration of these structures and uses a step-by-step approach to scientifically analyze each stage in the construction process. The Exhibition also provides opportunities to experiment with creative methods related to mathematical art.

5 Learning Activities & Effective Learning Environments

Science topic: Mathematics, Engineering, Technology, Science, Art (Relevance to national curriculum) Junior High School curriculum; Bridging the gap between formal education and informal learning; **Phenomenon Based Learning (PBL)** in Finland National Curriculum Class information Year Group: 6th grade of Junior high school Age range: 11-13 years Sex: all Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **The "Art of Math" exhibition: 11 interactive exhibits and demonstrations. Pronted materials are used for introduction and evaluation. Web-site is utilized as remote learning also from home.** Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? **The pre-learning will take place in the classroom settings as multiplicinary lessons of mathematics, physics, technology, handigraft, and art lessons.** **The exhibition visit takes place in the University settings, and in the Science Centre Post-lessons will take place in the school classroom using art lessons with ict-solutions.** Health and Safety implications? **Regular safety and first aid principles repeated before each phase** Technology? **Web-based pre-material supporting the learning in pre-lessons. Use of videos, photos, mobile phones and social media in the exhibition. Laptops and tablets used during the post-lesssons at school** Teacher support? **Tutorial role with introduction to process**

Prior pupil knowledge

Earlier mathematics knowledge, especially geometry, is repeated iin the school classroom lessons. According the National Curriculum of Finland they use PBL-Phenomenon-Based-Learning as their own project while teacher has more tutorial role.

Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)

During this scenario, students will

Month 1: During the pre-lessons of mathematics, science, technology, engineering and art, the practical use of mathematics in every-day-life is discovered and started to observe. Situation motivation is created to engage with mathematical themes and topics in practice. According the National Curriculum of Finland they use PBL-Phenomenon-Based-Learning as their own project while teacher has more tutorial role. They form a general group, depending on their interest in participating to the project. They use exhibition website and search the internet to find relevant information about the mathematical solutions bridging the gap between formal education and informal learning. Cognitive knowledge learning related to school mathematic are repeated during the period.

Months 2: Visiting the exhibition "Art of Math" in the local university and science centre the pupils receive and acquire a deeper understanding of the topics examined and especially the link between mathematics, aesthetics, and art. Colloborative working as pairs and groups in the open leaning environment like exhibition will give them first the situation motivation basis which gradually is enghanced into intrinsic motivation and deeper learning strategy. The science centre pedagogy experts are supporting this learning process with the two exhibition guides, Teacher has tutorial role. Pupils will learn cognitive knowledge which is giving practical and pragmatic added value especially in geometry from informal learning related to school mathematics.

Month 3: *Bridging is needed for transfer:* One of the most important findings is that the experience of the hands-on effectiveness or worth of mathematics showed to be distinct entities, and in pupils' minds the school and the exhibition are likely to form quite different worlds. Thus, it is important that the "Art of Math" project - as well as other similar projects in the future - do not remain simply as one more fun experience. Instead, it is important that the learned observation and thinking skills transfer into the further mathematical studies of pupils.
Month 4: To ensure the learning and motivation effects, teachers need to wisely support their pupils to build a bridge and make a connection between learning at the exhibition and learning in the classroom. Further, this will help to find the meaning of the math and art approaches and in the end the meaning of mathematics itself.

Assessment	Differentiation	
Pupils will fullfil their portfolio consisting of 1) pre-planning worksheet, 2) exhibition visit task and notes, 3) post-work with ict creating a report. In addition, they will use the videos and photos by which they documented the exhibition visit. In addition, the learning context Semantic Differential assessment is giving information about the relation of formal classroom education and informal exhibition learning.	How can the activities be adapted to the needs of individual pupils? **The central aim underlying educational methodology is to activate students' familiarity with geometric structures within the context of problem-solving. This method is based upon the creative exploration of these structures and uses a step-by-step approach to scientifically analyze each stage in the construction process. Individual, pair, and colloborative group work provides opportunities to experiment with creative methods related to mathematical art for different type of learners.**	**Key Concepts and Terminology** **Science terminology:** **Mathematics, figure, number, zero, Geometry, Pythagoras, venn-diagrams, Fibonacci, Chaos-theory, double-cone** **Arts terminology: figure golden split, perspective, form, harmony, rhythm, colour, interpretation, symbolism**

	data.	

Session Objectives: During this scenario, students will **deepen their understanding on scientific concepts and phenomena, using their creativity and imagination**				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Balance and navigation through dialogue aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through dialogue between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through dialogue interdisciplinarity and personal, embodied learning. Ethics and trusteeship is an important consideration in experimental design	+use the pre- and post-materials + visiting the exhibition +bridging the gap between formal education and informal learning and see the practical social impact +motivation build interest in mathematical scientific issues	The teacher gives as a tuto an opportunity for the pupils t utilize Exhibitic as an open learning environment	**The same topic is learned in the Art lessons, and Handicraft lessons. "Art of Math" exhibition is prepared with concepts like "harmony", "visual", "perspective"**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from individual, collaborative and communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. Risk, immersion and play is crucial in empowering pupils to generate, question and discuss evidence.	Students in the Exhibition +Explore +Empirical testing +Experiment repeated +Evaluate phenomena +They form groups for PBL-Phenomenon-Based-Learning	The teacher identifies possible misconceptions.	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using dialogue with each other and creating the portfolio	Students engage in analysing data – especially by finding independtly and as collaborative learning by internet	Tutorial role	

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider possibilities for explanations that are original to them.	Pupils compare the post-knwledge evalutation questionnairewith the answer options:Right-Wrong- I don't knowparticularly those reflecting scientific understanding.	Act as leaeder for reducing the uncertainty in knowing	Provide creative solutions as re-framing process

Phase 5: **CONNECT:** pupils connect explanations to practical everyday phenomenon and scientific knowledge	Pupils connect their explanations with everyday phenomena and scientific knowledge, using different ways of thinking and knowing (especially empirical experimenting) to relate their ideas to both disciplinary knowledge and to interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Explore the topic also aestethically and find connections with other disciplines. technology vs. design engineering vs. architecture. Exploration of new areas according to interests	Offers possibilities for finding extra-curricular information supporting the collaborative and individual learning	Creative re-framing process: seeing phenomenon in new light and different approach angle

Phase 6: **COMMUNICATE:** pupils disseminate the information	- Ideas and justifications through dialogue with other pupils - Communication of possibilities : - with pupils outside own classroom - e-mail questions to science centre experts educators, - ethical approach: taking into account the responsible research aspects	Pupils two-way- communicate with professionals (science centre experts) in order to get fulfilling information related to steAm – Art aspects	Tutorial	Repeating the post-knowledge questionnaire and finding creative everyday solutions for STEAM

Phase 7: **REFLECT:** pupils find own solutions for "Bridging the gap between formal education and informal learning"	The use of open learning environments, collaborative and community-based actions. The content of Phenomenon-Based-Learning (PBL) in the National Curriculum of Finland – pupils analyse of everyday Mathematics and Art	Fulfilling their Portfolio related to Phenomenon-Based-Learning (PBL).	Teacher reports the reached learning and motivational results in VILMA-ICT-network shared with parents	Results widely disseminated via VILMA-ICT and school administration

6 Additional Information

Additional information on the "Math & Art Exhibtion" can be found at:

- http https://www.youtube.com/watch?v=rexr77S3FbU
- https://www.energiakeskus.ee/tegevused-post/avasta-matemaatikakunst/
- https://www.jyu.fi/erillis/museo/ajankohtaista-1/tangram-2013-matematiikan-ja-taiteen-kohtaamisia-nayttelykeskus-soihdussa-8-3-20134-6.2016/

So pictures are provided below.





7 Assessment

Thuneberg, H. & Salmi, H. & Fenyvesi, K. 2017: Hands-on "Math and Art" Exhibition promoting science attitudes and educational plans. Educational Research International, Article ID 9132791, 13 pages.

see:

- http://dx.doi.org/10.1155/2017/9132791

All in all, the hands-on and art approach to math involving touching and seeing helped pupils to produce creative results, which otherwise would not have come into the world. In the building project pupils had to continuously change from the observation of details to observing the whole and back, which prevented pupils from becoming stuck and which supported the testing of ideas and flexible thinking – a prerequisite of development of cognition and creativity. According to Hope [19] the visual representation shows the cognitive learning outcome, the thinking results of the pupils, and how they have found the key spatial characteristics of the problem in concern. One can assume that this kind of process also promotes consciousness and meta-cognition in students, which are important goals of math education [15]. As such, the next step concerning the project will be most interesting, as we will use video analysis and focus on examination of the building process and the resulting visual models.

In fact, the process of building the hands-on Art & Math structures resembled a lot the process of computer programming, where everything is based on totally reduced units of 1 and 0. In the 4-D Math system the pupils had only four types of units to create different structures and creatures. Now, bridging the gap between the general mathematical competence and the increasingly computational contemporary culture, the power of curiosity, imagination, and play by Görlizt [65] are forming the link between the real material world and the totally digitalized environments.

Abstract

The current STEAM-education approach emphazises integration of abstract science and mathematical ideas for concrete solutions and evidence by art. The study participants (N=256) were 12-13 years old from Finland. The main aim was to find out how experience of learning mathematics differed between the contexts of school and an informal Math and

Art exhibition. The results based on GLM modeling and SEM path modeling underline the motivational effects. The experience of the effectiveness of hands-on learning at school and at the exhibition was not consistent across the subgroups. The lowest achieving group appreciated the exhibition alternative for math learning compared to learning math at school. The boys considered the exhibition to be more useful than the girls as it fostered their science and technology attitudes. However, for the girls the attractiveness of the exhibition, the experienced situation motivation, was much more strongly connected to the attitudes on science and technology and the worthiness of mathematics. The results indicated that there is the risk that the pupils do not see the connection between the different learning contexts of the traditional class-room and an out-of-school exhibition. Interestingly, the pupils experienced that even this short informal learning intervention affected their science and technology attitudes and educational plans.

Keywords: STEAM, math learning, hands-on, art, informal learning, motivation

8 Possible Extension

Through the “Math & Art Exhibition” became an immediate success, and the original exhibtion as well as copy of it has been disseminated and copied to science centres and exhibitions to following places: Tallinn, Estonia; Cesis, Latvia; Trollhättan, Sweden; and Stockholm, Sweden; Jyväskylä, Finland; Helsinki, Finland.

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D3.2.64 "4-D Math and Art Workshop"

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Code:	D 3.2.64	**Contributors:**	
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1 Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics, Art, Science, Technology, Engineering

1.2 Type of Activity

Informal – Out-of-school Large scale National Activities

1.3 Duration

3 months

1.4 Setting (formal / informal learning)

Formal and informal. *4-D Math and Art Workshop* is bridging the gap between formal education and informal learning. Interdisciplinary STEAM Pre- and Post-activities in the classroom before and after the workshop support the process.

1.5 Effective Learning Environment

- Visits to university research centres (virtual/physical)
- Communication of scientific ideas to audience
- Communities of practice
- Arts-based
- Ethics
- Simulations
- Experimentation (Science laboratories and eScience applications)

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2 Rational of the Activity / Educational Approach

2.1 Challenge

Learning of mathematics most often happens unconsciously. This is typically informal learning [2], which can also be utilized in a science exhibition context [3]. However, the older the children become the more complicated the mathematical problems they encounter in everyday situations and especially when they start school. Then it becomes crucial to exploit childrens'natural curiosity, imagination, and willingness to play in the learning of mathematics and to support them to discover the meaningfulness and worth of mathematics. According to the TIMSS 2015–study (TIMMS= Trends in International Mathematics and Science Study), half of the international fourth grade Mathematics curricula include attitudes and mention, for example, beliefs, confidence, and perseverance as well as the beauty of mathematics, developing a productive disposition toward mathematics, appreciating the practical applications of mathematics in life, and displaying a constructively critical attitude toward mathematics [4]. Some countries mention appreciation of scientific inquiry and science as a discipline or a curiosity and interest.

2.2 Added Value

In this Demonstrator, mathematical problem solving was combined with art. The learning context is a ***4-D Math and Art Workshop***, and the mix of math learning and art was represented in the building of mathematical geometric models with concrete materials. These activities require visual imagery and mental rotation. According to Hope [19], the capacity and skill to create visual representations of the mental images form an essential part of the learning process. Although the immediate goal was to enhance math learning, these activities support the development of spatial skills [20] and spatial intelligence, which have been identified as important factors of school achievement in general [21].

According to Fenyvesi, Koskimaa, and Lavicza [22] problem-solving can also be a basis for the integration of learning mathematics in transdisciplinary educational frameworks, such as STEAM-integration, although the integration of liberal arts into STEM is mutually reshaping scientific education and humanities education [23]. It seems evident that just like mathematics learning, it is recommended that science, technology, engineering, and arts education also follow problem-oriented approaches.

As the creative element and aesthetic component are the inherent core of art, combining art with math learning offers an additional dimension for concretizising math concepts. Art and

math have been considered to share many principles, for example space and shape [24], but also that of aesthetics, as Mack [25] discusses in his article "A Deweyan perspective on aesthetic in mathematics education". The synthesis of math and art might show the beauty of both domains and possibly in a novel light. As such, by applying art ways of looking and observing become critical [26, 27, 28].

3 Learning Objectives

3.1 Domain specific objectives

The main objective of the ***Art of Math Exhibition*** is to give to the **high school pupils (average age 11-13 years) an opportunity to use hands-on creative mathematical exhibits and interactive mathematical structures as cooperative group work to learn scientific, technological and engineering concepts by using art and handicraft exhibit demonstrators.**

Art of Math Exhibition domain specific objectives are to:

- Get students motivated in mathematics and STEM through Art orientated exhibition
- Teach pupils how to explore a mathematical structure with aesthetic aspects
- Initiate the development of *learning by doing*, regarding a visual mathematical topic
- Initiate contact between students and other professionals (for example university mathematians, science centre experts, and artists)
- Bridging the gap between formal education and informal learning
- Engage parents and the general public into out-of-school happenings and events
- Build National-wide pupils networks
- Open the school to the community and involve all the stakeholders.

Connecting to these main objectives, peripheral aims are formed addressing pupils' needs to:

- develop art abilities necessary to do mathematical and STEM inquiry
- develop encourage for scientific testing
- identify questions and concepts for empirical exploring in exhibition context
- design and conduct relevant and pragmatic solutions to scientific concepts and issues

- use technology to improve investigations, communications and the development of simple engineering solutions
- show the cooperative nature of scientific research as group work in an open learning environment
- learning to find information independently from the combination of exhibits
- creativity and imagination as starting point for formulating hypothesis
- recognize, analyze and imagine alternative explanations and models
- communicate a scientific argument or issue in a creative way
- develop lifelong learning skills
- taking into account the ethics, sustainability and responsible research
- link with science and society in a personal context

3.2 General skills objectives

In the context of the ***Art of Math Exhibition***, students' general skills objectives are:

- Hands-on activities with learning by doing -principle
- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of mathematical concepts and phenomena
- Scientific interconnection of mathematics, engineering, technology and science science with aspects of art (students will create a multidisciplinary STEM construction with clear artistic approach with hands-on workshop, which demonstrates and deepens understanding, supporting discipline knowledge in both the STEM and Arts & Skills educational disciplines).
- Develop spirit of cooperation and teamwork while exploring together the Exhibition
- Connect the science classroom with professionals and local communities
- Bridging the gap between formal education and informal learning

More Specifically:

- Pupils will learn by the Exhibition hands-on solutions about scientific concepts related to the curriculum of their courses with adding from informal learning sources

- Pupils will become involved and acquainted with the concept of learning mathematics creatively via ***Art of Math Exhibition***. Art & Skills are related to traditional STEM will lead them to "learning by doing" process and deepen their multi-discipline knowledge.
- Creative element is underlined in the open learning environment with structured goals. Pupils should also be specific about key concepts they will be focusing on.
- In the Exhibition pupils will deal with mathematical knowledge and experience with group-work in which scientific models and figures can be of great inspiration to Engineering and Tech via Art
- The students should be able to describe fundamental concepts concerning their chosen topic.
- Combining math learning with experimentation and art in a concrete model in the exhibition creates a many-sided and versatile approach.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to high school students aged from 11 to 13 years old to combine math learning with experimentation and art in a concrete testng process in the exhibition as a many-sided and versatile approach. In this open learning environment of ***Art of Math Exhibition*** pupils in learn effectively by hands-on method. In this way, students learn aesthetic mathematics and science in a creative way by art and skills.

The context of the ***Art of Math Exhibition*** is a modern, mobile, and interactive exhibition. The exhibition consisted of eleven interactive, "hands-on" science exhibition objects, which the students were allowed to use, test, explore, and learn freely during a 45-minute time period. Following that they attended a workshop (also 45 minutes) in which they were allowed to build their own structures and creatures by using and applying the small "lego" type of plastic pipes and circles.

The participants in Math and Art exhibition were 11 to 13 years old from several areas, villages, towns and cities in Finland (N=556), gender equally 52% girls and 48% boys.

At least one teacher is responsible for each school/participation with the support of the science centre pedagogist and the exhibition guide. The new National Curriculum of Finland demands the teacher to use Phenomenon Based Learning (PBL). Students and teachers select a science theme that would like to develop as a STEAM-project. In this way, it is given the opportunity to pupils to inquire about mathematical, technological, engineering, and scientific concepts and issues of their interest and express their findings in creative ways.

4.2 Student needs addressed

The ***Art of Math Exhibition*** demonstrator offers the opportunity for the enhancement of the pupils' cognitive involvement, their representation of scientific content using their interactive cognitive processes, the pupils' hands-on involvement using the hands-on exbibits. As an open learning environment, the ***Art of Math Exhibition*** underlines the cooperative exploring with emotional involvement. Learning as group work advances the social interaction and communication. Teachers, science centre experts, guides, artists, parents, and other adults have a tutorial supportive role in the learning process.

Situation motivation's role is essential in change of attitudes towards mathematics, science and technology and future educational plans. According the research literature ituation motivation was the most powerful explainer especially in regard to the experienced Exhibition influences on science and technology attitudes, and it also affected future educational plans. These results imply increased meta-cognition, the awareness of what one thinks and plans, like Lai, Zhu, Chen, and Li [15, p.2] observed: "Motivation is an important energizing factor of metacognition and can activate the self-regulation process". Situation motivation is boosted by relative autonomy experience.

The central aim underlying ***Art of Math Exhibition*** demonstrator educational methodology [37] is to activate pupils' familiarity with concrete, clear, aesthetic geometric structures within the context of problem-solving. This method is based upon the creative exploration of these structures and uses a step-by-step approach to scientifically analyze each stage in the construction process. The Exhibition also provides opportunities to experiment with creative methods related to mathematical art.

5 Learning Activities & Effective Learning Environments

Science topic: Mathematics, Engineering, Technology, Science, Art (Relevance to national curriculum) Junior High School curriculum; Bridging the gap between formal education and informal learning; **Phenomenon Based Learning (PBL)** in Finland National Curriculum Class information Year Group: 6th grade of Junior high school Age range: 11-13 years Sex: all Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **The "Art of Math" exhibition: 11 interactive exhibits and demonstrations. Pronted materials are used for introduction and evaluation. Web-site is utilized as remote learning also from home.** Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? **The pre-learning will take place in the classroom settings as multiplicinary lessons of mathematics, physics, technology, handigraft, and art lessons.** **The exhibition visit takes place in the University settings, and in the Science Centre Post-lessons will take place in the school classroom using art lessons with ict-solutions.** Health and Safety implications? **Regular safety and first aid principles repeated before each phase** Technology? **Web-based pre-material supporting the learning in pre-lessons. Use of videos, photos, mobile phones and social media in the exhibition. Laptops and tablets used during the post-lesssons at school** Teacher support? **Tutorial role with introduction to process**

Prior pupil knowledge

Earlier mathematics knowledge, especially geometry, is repeated iin the school classroom lessons. According the National Curriculum of Finland they use PBL-Phenomenon-Based-Learning as their own project while teacher has more tutorial role.

Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)

During this scenario, students will

Month 1: During the pre-lessons of mathematics, science, technology, engineering and art, the practical use of mathematics in every-day-life is discovered and started to observe. Situation motivation is created to engage with mathematical themes and topics in practice. According the National Curriculum of Finland they use PBL-Phenomenon-Based-Learning as their own project while teacher has more tutorial role. They form a general group, depending on their interest in participating to the project. They use exhibition website and search the internet to find relevant information about the mathematical solutions bridging the gap between formal education and informal learning. Cognitive knowledge learning related to school mathematic are repeated during the period.

Months 2: Visiting the exhibition "Art of Math" in the local university and science centre the pupils receive and acquire a deeper understanding of the topics examined and especially the link between mathematics, aesthetics, and art. Colloborative working as pairs and groups in the open leaning environment like exhibition will give them first the situation motivation basis which gradually is enghanced into intrinsic motivation and deeper learning strategy. The science centre pedagogy experts are supporting this learning process with the two exhibition guides, Teacher has tutorial role. Pupils will learn cognitive knowledge which is giving practical and pragmatic added value especially in geometry from informal learning related to school mathematics.

Month 3: ***Bridging is needed for transfer:*** **One of the most important findings is that the experience of the hands-on effectiveness or worth of mathematics showed to be distinct entities, and in pupils' minds the school and the exhibition are likely to form quite different worlds. Thus, it is important that the "Art of Math" project - as well as other similar projects in the future - do not remain simply as one more fun experience. Instead, it is important that the learned observation and thinking skills transfer into the further mathematical studies of pupils.**

Month 4: To ensure the learning and motivation effects, teachers need to wisely support their pupils to build a bridge and make a connection between learning at the exhibition and learning in the classroom. Further, this will help to find the meaning of the math and art approaches and in the end the meaning of mathematics itself.

Assessment	Differentiation	
Pupils will fullfil their portfolio consisting of 1) pre-planning worksheet, 2) exhibition visit task and notes, 3) post-work with ict creating a report. In addition, they will use the videos and photos by which they documented the exhibition visit. In addition, the learning context Semantic Differential assessment is giving information about the relation of formal classroom education and informal exhibition learning.	How can the activities be adapted to the needs of individual pupils? **The central aim underlying educational methodology is to activate students' familiarity with geometric structures within the context of problem-solving. This method is based upon the creative exploration of these structures and uses a step-by-step approach to scientifically analyze each stage in the construction process. Individual, pair, and colloborative group work provides opportunities to experiment with creative methods related to mathematical art for different type of learners.**	**Key Concepts and Terminology** **Science terminology:** **Mathematics, figure, number, zero, Geometry, Pythagoras, venn-diagrams, Fibonacci, Chaos-theory, double-cone** **Arts terminology: figure golden split, perspective, form, harmony, rhythm, colour, interpretation, symbolism**

	data.	

Session Objectives:

During this scenario, students will **deepen their understanding on scientific concepts and phenomena, using their creativity and imagination**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**

Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Balance and navigation through dialogue aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through dialogue between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through dialogue interdisciplinarity and personal, embodied learning. Ethics and trusteeship is an important consideration in experimental design	+use the pre- and post-materials + visiting the exhibition +bridging the gap between formal education and informal learning and see the practical social impact +motivation build interest in mathematical scientific issues	The teacher gives as a tuto an opportunity for the pupils t utilize Exhibitic as an open learning environment	**The same topic is learned in the Art lessons, and Handicraft lessons. "Art of Math" exhibition is prepared with concepts like "harmony", "visual", "perspective"**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from individual, collaborative and communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. Risk, immersion and play is crucial in empowering pupils to generate, question and discuss evidence.	Students in the Exhibition +Explore +Empirical testing +Experiment repeated +Evaluate phenomena +They form groups for PBL-Phenomenon-Based-Learning	The teacher identifies possible misconceptions.	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using dialogue with each other and creating the portfolio	Students engage in analysing data – especially by finding independtly and as collaborative learning by internet	Tutorial role	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider possibilities for explanations that are original to them.	Pupils compare the post-knwledge evalutation questionnairewith the answer options:Right- Wrong- I don't knowparticularly those reflecting scientific understanding.	Act as leaeder for reducing the uncertainty in knowing	Provide creative solutions as re-framing process

Phase 5: **CONNECT:** pupils connect explanations to practical everyday phenomenon and scientific knowledge	Pupils connect their explanations with everyday phenomena and scientific knowledge, using different ways of thinking and knowing (especially empirical experimenting) to relate their ideas to both disciplinary knowledge and to interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Explore the topic also aestethically and find connections with other disciplines. technology vs. design engineering vs. architecture. Exploration of new areas according to interests	Offers possibilities for finding extra-curricular information supporting the collaborative and individual learning	Creative re-framing process: seeing phenomenon in new light and different approach angle

Phase 6: **COMMUNICATE:** pupils disseminate the information	- Ideas and justifications through dialogue with other pupils - Communication of possibilities : - with pupils outside own classroom - e-mail questions to science centre experts educators, - ethical approach: taking into account the responsible research aspects	Pupils two-way- communicate with professionals (science centre experts) in order to get fulfilling information related to steAm – Art aspects	Tutorial	Repeating the post-knowledge questionnaire and finding creative everyday solutions for STEAM

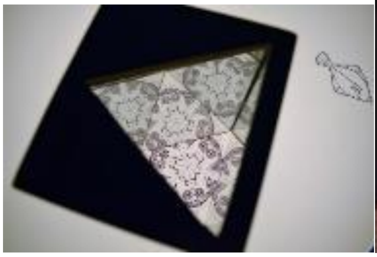
Phase 7: **REFLECT:** pupils find own solutions for "Bridging the gap between formal education and informal learning"	The use of open learning environments, collaborative and community-based actions. The content of Phenomenon-Based-Learning (PBL) in the National Curriculum of Finland – pupils analyse of everyday Mathematics and Art	Fulfilling their Portfolio related to Phenomenon-Based-Learning (PBL).	Teacher reports the reached learning and motivational results in VILMA-ICT-network shared with parents	Results widely disseminated via VILMA-ICT and school administration

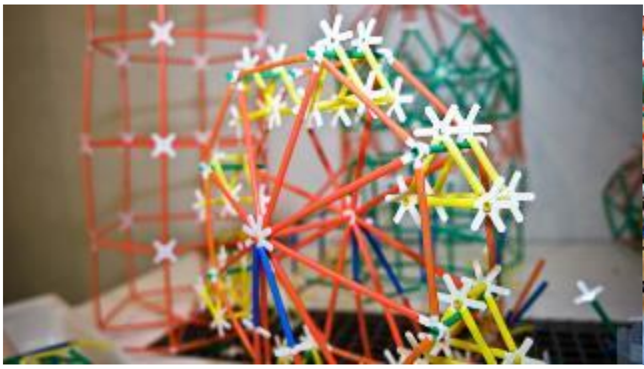
6 Additional Information

Additional information on the "4-D Math & Art Workshop" can be found at:

- http https://www.youtube.com/watch?v=rexr77S3FbU
- https://www.energiakeskus.ee/tegevused-post/avasta-matemaatikakunst/
- https://www.jyu.fi/erillis/museo/ajankohtaista-1/tangram-2013-matematiikan-ja-taiteen-kohtaamisia-nayttelykeskus-soihdussa-8-3-20134-6.2016/

So pictures are provided below.





CREATIONS has received funding from the European Commission HORIZON2020 Programme

7 Assessment

Thuneberg, H. & Salmi, H. & Fenyvesi, K. 2017: Hands-on "Math and Art" Exhibition promoting science attitudes and educational plans. Educational Research International, Article ID 9132791, 13 pages.

see:

- http://dx.doi.org/10.1155/2017/9132791

All in all, the hands-on and art approach to math involving touching and seeing helped pupils to produce creative results, which otherwise would not have come into the world. In the building project pupils had to continuously change from the observation of details to observing the whole and back, which prevented pupils from becoming stuck and which supported the testing of ideas and flexible thinking – a prerequisite of development of cognition and creativity. According to Hope [19] the visual representation shows the cognitive learning outcome, the thinking results of the pupils, and how they have found the key spatial characteristics of the problem in concern. One can assume that this kind of process also promotes consciousness and meta-cognition in students, which are important goals of math education [15]. As such, the next step concerning the project will be most interesting, as we will use video analysis and focus on examination of the building process and the resulting visual models.

In fact, the process of building the hands-on Art & Math structures resembled a lot the process of computer programming, where everything is based on totally reduced units of 1 and 0. In the 4-D Math system the pupils had only four types of units to create different structures and creatures. Now, bridging the gap between the general mathematical competence and the increasingly computational contemporary culture, the power of curiosity, imagination, and play by Görlizt [65] are forming the link between the real material world and the totally digitalized environments.

Abstract

The current STEAM-education approach emphasizes integration of abstract science and mathematical ideas for concrete solutions and evidence by art. The study participants (N=256) were 12-13 years old from Finland. The main aim was to find out how experience of learning mathematics differed between the contexts of school and an informal Math and Art exhibition. The results based on GLM modeling and SEM path modeling underline

the motivational effects. The experience of the effectiveness of hands-on learning at school and at the exhibition was not consistent across the subgroups. The lowest achieving group appreciated the exhibition alternative for math learning compared to learning math at school. The boys considered the exhibition to be more useful than the girls as it fostered their science and technology attitudes. However, for the girls the attractiveness of the exhibition, the experienced situation motivation, was much more strongly connected to the attitudes on science and technology and the worthiness of mathematics. The results indicated that there is the risk that the pupils do not see the connection between the different learning contexts of the traditional class-room and an out-of-school exhibition. Interestingly, the pupils experienced that even this short informal learning intervention affected their science and technology attitudes and educational plans.

Keywords: STEAM, math learning, hands-on, art, informal learning, motivation

8 Possible Extension

Through the "4-D Math&art Workshop " became an immediate success, and the Workshop was repeated in University of Helsinki premises in Oct-Nov 2017; and will be repeated for puplips, teachers and teacher trainees in Helsinki and Jyväskylä in Feb-March 2018.

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.65 AR Memory Game

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Alexander Gerber,** Bernd Müller, Paola Jibaja
Code:	D 3.2.65.	**Contributors:**
Version & Date:		**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Biology, and others

1.2 Type of Activity

The specific activity is a combination of
School based and
School - research center collaboration
The activity has been developed as a local activity but can be adapted to national level

1.3 Duration

2 h

1.4 Setting (formal / informal learning)

Both formal and informal. The setting involves formal learning as well as exploration of knowledge through an approach with an Augmented Reality game.

Formal and Informal learning settings are
Classroom
Augmented Reality

1.5 Effective Learning Environment

Simulations
Dialogic Space / argumentation
Art-based effective learning environment, e.g.
- Time/space to extend the game by combining other fields of research with own artistic ideas
- Time/space to develop a storyline of a dramatic scene to bring the female scientists alive

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

The way science has been taught in classrooms has conventionally concentrated on facts and routine learning (Clark et al., 2009). However, some scholars argue that current teaching methods are not effective on developing these skills since they are memoristic and obsolete, resulting in a lack of interest for science in students (National Research Council, 2011).

In response to this situation, new teaching methods have to be developed, allowing students to take a more active role on science learning. One of these methods is the use of serious games (gamification), which aims to motivate students with challenges, fostering practice, providing immediate feedback and enabling them to learn science-related topics in a more playful way (National Research Council, 2011).

According to Barab and Dede (2007), virtual science games help students to identify more with science and with learning processes related to them. This is due to the fact that learners consider that science education is more important and effective when communication technologies are applied. Furthermore, virtual science games can be used through different platforms, such as cell phones, tablets, computers, game consoles, etc. providing a variety of tools to engage students in learning science (National Research Council, 2011).

Games that use this kind of technology enable the player to relate certain digital information with real context (Billinghurst and Duenser 2012, Antonioli et al. 2014 & Cabero and García 2016). There are two variants of AR: location-aware and vision-based (Dunleavy and Dede, in press). In the first, participants are presented with digital information while they are moving through a specific physical area. While in the second, digital information is presented to them after they have directed the camera of their device to a certain point (Dunleavy and Dede, in press).

In mixed-reality games, the physical body interacts with physical objects and 3D gestures, as well as with digital components (Birchfield et al. 2006). It has specific characteristics, such as: offering the possibility of integrating different layers of information at the same time by means of using different types of formats (e.g. texts, videos, URL) and enriching or altering the information of reality by adding virtual information (Cabero and García, 2016).

In this sense AR presents itself as a significant technology for the creation of games, supporting game-based learning and learning based on discovery (Fundación Telefónica, 2011).

It is important to emphasise that this kind of technology allows students to appreciate the reality that surrounds them from another perspective, relating it to what they learn (Klopfer and Sheldon, 2010). Moreover, AR games allow immersive learning, which is defined by Dede (2009) as the person's perception that he or she is living an authentic or real experience. This experience improves teaching in three ways: broadens perspectives, generates situated learning and offers the possibility of transferring what has been learned to the real world (Dede, 2009).

Furthermore, with respect to the relationship between gender and science, according to Beirute, et al. (2007), this relationship is influenced by different variables, such as social construction processes occurring among the media (which have the ability to create social representations and maintain the hegemony of certain positions), the school (space where knowledge-related competencies are acquired) and the family. This causes that certain beliefs, practices and preferences are not questioned, hindering the possibility of diversifying and expanding social thinking between gender and science (Beirute, et al., 2007).

Regarding the belief that men do better at mathematics than women, this stereotype remains valid despite the evidence that academic achievement in mathematics is very similar between men and women (Hedges and Nowell, 1995; Hyde, et al., 1990; Hyde, et al., 2008, as quoted in Else-Quest, et al., 2010, p.103). This causes gender differences when teaching and learning mathematics. However, such differences can be modified when female students are encouraged to succeed, are given necessary tools to learn the subject and have outstanding female role models in mathematics (Else-Quest, et al., 2010).

2.2 Added Value

The so called game-based learning or gamification is a didactic methodology that is gaining significance in recent times (Durall et al., 2012). This learning methodology has demonstrated to support immersive and experiential learning, cognitive development and skill acquisition by students (Durall et al., 2012). In addition, Klopfer (2008) mentions that games can allow students to learn certain contents in a faster way than using traditional teaching methods. Wu et al. (2016), complement this belief adding that a number of studies support game-based learning since games can increase students' dedication to their studies and are more attractive than conventional instructional methods. Also gamification could lead to a more gender equal access to learning of science and new scientific careers.

The general positive consequences observed when using AR versus non-AR systems is that it takes place in new spatial environments which stimulates visible learning and language associations in a different way. This leads to a new approach of content understanding and long-term memory retention. The AR game is designed to improve collaboration and teamwork and leads to improved motivation.

With this in mind the students will benefit from higher score in the post-matching quiz compared to conventional teaching, after being exposed to the AR memory game. Female students will report a higher satisfaction level from this activity. This could lead to gender equality in scientific careers.

3. Learning Objectives

3.1 Domain specific objectives

The domain specific objectives are:

- Get students interested in science and research through Augmented Reality
- Boost knowledge about female scientists in history and their achievements
- Better memorize the information presented in the game
- Reach a higher level of satisfaction for female students compared to non-AR approach
- Show that science offers career opportunities also for female students
- Learn how to interact with AR technology

3.2 General skills objectives

Please describe the skills that will be developed according to your demonstrator. As an example, see below:
Students' general skills objectives are:

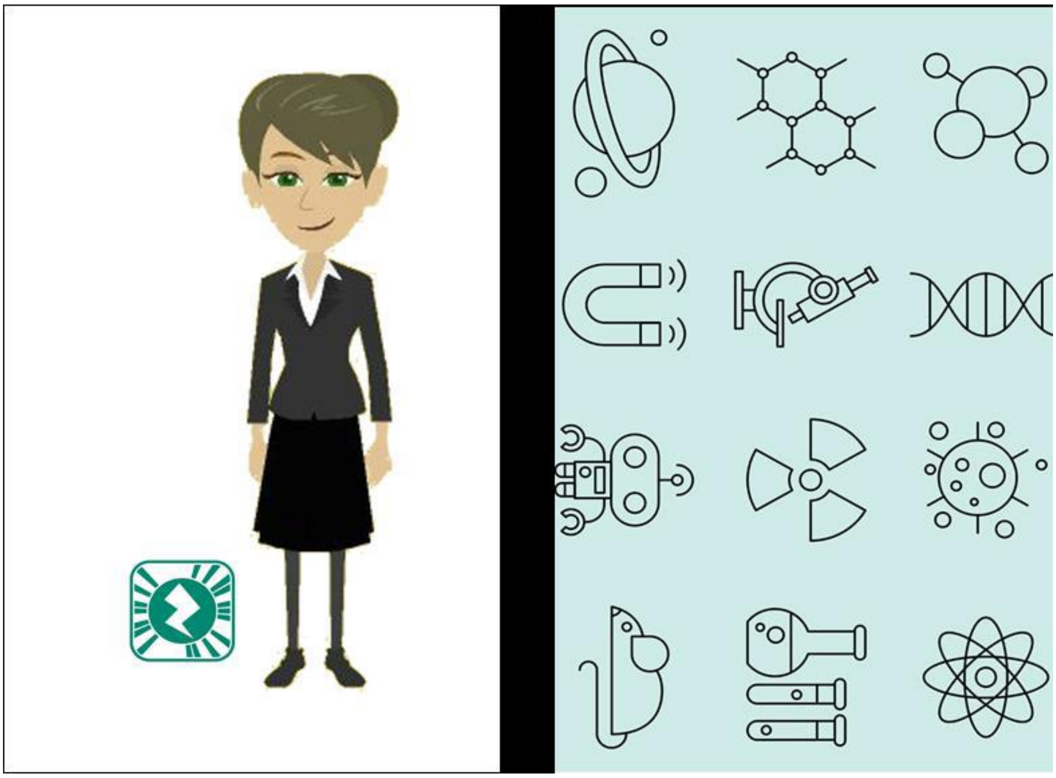
- Make use of new technology and serious games
- Develop memorizing skills
- Understanding scientific concepts and phenomena
- Discuss gender related questions in science
- Provide scientific female role models

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Students play an Augmented Reality science memory game. The AR memory game was developed by Marie Loedige and Allison-Jane Zaman as a course project in the Bachelor programme Science Communication and Bionics and supervised by Prof. Alexander Gerber from Rhine-Waal University of Applied Sciences (2017).

The game is a physical/traditional memory card game enhanced by Augmented Reality and it can be described as a mixed-reality game about contemporary and historical female scientists. In this memory game, the players link scientists to their respective area of expertise or research field. For example, Valentina Vladimirovna Tereshkova will be linked as the first woman to travel into space or Jane Goodall will be linked as an experienced researcher on chimpanzees and primates. The playing cards have a Quick Response (QR) code printed on them that, when scanned with a smartphone or tablet, displays a video with information about a scientist.



Front and back design of the cards.

First, one player prepares and shuffles the playing cards and lays them down face onto the table. Afterwards, a player begins by flipping any 2 cards over. Then, he scans the code on the card with a smartphone or

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tablet. The application Zappar is used to identify the QR codes on the cards. After identifying the code, Zappar superimposes the corresponding information onto the card, and then displays the models and animations on the screen. The players can then view a combination of a real object with virtual information.

Procedure of processing the AR interactive memory game card

The game will help to improve knowledge about female scientists in an entertaining way, as well as provide students with scientific female role models.

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4.2 Student needs addressed

Students needs are addressed by setting up a playful environment by using a well accepted tool like their own smartphones. This increases motivation and combines knowledge in a more playful way with something they already know. Moreover the AR game increases curiosity since it is still little used in learning environments.

Students don´t need any specific basic knowledge. A creative and collaborative learning environment should be provided as well as support by the teachers to answer technical questions. Students need persistent assessment which is given by the game itself.

5. Learning Activities & Effective Learning Environments

Science topic: Female scientists (Relevance to national curriculum) Class information Year Group: 9th grade Age range: 13-15 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) *Where will the learning take place? School or university* *On site or off site? On site* *In several spaces? (e.g. science laboratory, drama space etc), or one? In a room that can facilitate lecture and group work* *Health and Safety implications? none* *Technology? Tablet computer and pinboard* *Teacher support? Yes. To encourage and help if necessary*
Prior pupil knowledge **none**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

- Listen to the introductory talk which explains the aim of the intervention
- Learn how to use memory cards and tablet for AR support
- Play memory with the cards and gather knowledge about famous female scientist
- Evaluate their knowledge with the AR game

Assessment	**Differentiation**	**Key Concepts and Terminology**
Self assessment in groups and with the AR quiz Teacher has to make sure that Creations features are taken into account, especially dialogue, interdisciplinarity and immersion (in the game itself)	*How can the activities be adapted to the needs of individual pupils?* Since there are no specific needs for the students to take part in this intervention, all students will benefit from it. Yet different capabilities of students can be taken into account by forming groups of similar abilities and adjusting the amount of cards/scientists.	**Science terminology:** Female scientists, gender equality, radioactivity, primates … (Can be expanded to any scientific field by adding cards) **Arts terminology:** Serious Gaming

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Session Objectives: During this scenario, students will get to know famous female scientists in different research areas and assess their knowledge in a AR-game.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design	Engage with information given by a memory and quiz game and through dialogue Build interest in scientific careers and their impact on female scientists as well on scientific progress	Activates students with questions about scientific careers and the roles of women in science. What was the major achievements of these scientists?	

	and collaborative work, as well as in the initial choice of question.	Get to know the variety of interdisciplinary approaches in science	How did their work change the world?	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students collaborate in finding information about the scientists Students are engaged in a game and highly immersed in AR-gaming	The teacher identifies possible misconceptions	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyze information about scientists and their achievements	Teacher divides students in groups and supports students with background	

			information about the scientists	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students discuss and explain the scientist´s work in the light of gender related topics	Acts as a facilitator of the process	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Find connections to other disciplines, careers, scientists	Allows room and connection to other scientists and roles	
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of	Groups communicate explanations and possibilities about careers in science	Assess students knowledge by evaluating the	

COMMUNICATE: students communicate and justify explanation	the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.		results of the AR game	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect on the inquiry process and their learning in the AR game	Assess students understanding after finishing the AR game	Students can use their knowledge to for a storyline of a dramatic scene to bring the female scientists alive

6. Additional Information

If you are interested in the CREATIONS´ approach you find more information on the website www.creations-project.eu.

Open Discovery Space Platform (http://portal.opendiscoveryspace.eu/creations) is an online platform where teachers and students have the opportunity to share their opinions and their educational resources for this and all other CREATIONS demonstrators.

CREATIONS project is also active on Scientix portal, the European platform for STEM teaching. If you are interested in STEM related information or if you are planning a collaboration with the CREATIONS project (implementation of demonstrators, teacher workshops etc.) you can contact your national ambassadors or the CREATIONS project partners.

7. Assessment

Pre-evaluation phase
First, students are asked to answer the Science Motivation Questionnaire for students (SMQ II) with the open question. The total amount of time for this activity is 10 minutes. Afterwards, students proceeded with the matching quiz, where they had 15 minutes to complete the quiz. All students complete the pre-evaluation phase individually and without being influenced by other students in the group.

After Intervention phase
After the intervention students are asked to fill in the states emotions (SE) questionnaire. After the intervention the researcher askes students to give some comments about the activity.

Post-evaluation phase
To measure perceptions and generic learning outcomes from the intervention, a certain period of time should be considered in between the pre- and post-evaluation. Due to this, the post-evaluation can be done after five days. First, students answer the SMQ II questionnaire and then solve the matching quiz. The procedure was the same as in the pre-evaluation phase.

During the implementation process a self-assessment through collaboration is taking place. Also the memory game gives immediate response if an answer is right or wrong by turning and scanning the card.

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8. Possible Extension

Demonstrator could be extended by

- Adding / exchange cards with different female scientists
- Using it for other disciplines and topics rather than gender in sciences. The AR game in general can be used for every domain where informations can be linked together. Examples are scientific instruments and research (CERN/LHC – finding new particles), Nobel price winners – research etc.

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D3.2.66 Planetary Evolution

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Code:	D 3.2.66.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Geology, Physics, Astronomy

1.2 Type of Activity

The specific activity is a school-based activity
The activity has been developed as a local activity but can be extended to an international activity (e.g. German-Dutch cross-border collaboration)

1.3 Duration

Workshop: 4 h
Work sessions, rehearsals: 4 weeks x 2h

1.4 Setting (formal / informal learning)

Formal and informal. The setting involves exploration of knowledge through performance art, hands-on experimentation, and play.

1.5 Effective Learning Environment

Dialogic space
Art- Based

2. Rational of the Activity / Educational Approach

2.1 Challenge

Students' knowledge about basic concepts of planetary systems and the formation of the Earth is rather limited because it is not in the main focus of schools' curriculum. On the other hand, the nature of geology and Earth seems to be of interest to many students.

A challenge for students is to imagine the processes in the formation of the planets and in the interior of the earth. Either these processes happened billions of years ago or they take place inside the earth, in any case they are invisible to the senses of the students. The challenge for the demonstrator is therefore to make these processes sensually tangible, for example through experiments that are not usually carried out in the classroom. In addition, the artistic implementation of what has been learned can help to find an alternative approach to the topic. This helps especially students who have difficulties with conventional teaching.

2.2 Added Value

Enquiry-based learning as a form of active learning starts by posing questions, problems or scenarios rather than simply presenting established facts or portraying a smooth path to knowledge. Inquirers will identify and research issues and questions to develop their knowledge or solutions. Inquiry-based learning includes problem-based learning, and is generally used in small scale investigations and projects, as well as research. The enquiry-based instruction is principally very closely related to the development and practice of thinking skills.
Through the principles of embodied learning, basic principles of epistemological knowledge and pedagogical theories can be combined, so that the student can utilize his body as a source of knowledge and feel alive and active during the learning process. αναφορές

Our initiative combines these two approaches. It uses embodied learning as a starting point for enquiry-based learning to acquire knowledge in geophysics and applies this knowledge in a third step for artistic expression. As such we provide a way to interlink both approaches in a flexible way.

The specific approach during the educational process leads to increased understanding, long-term memory retention, improved collaboration, improved motivation and confident use of artistic expression.

The benefits of this demonstrator for the students are a deeper understanding of processes forming the Earth, a higher motivation to engage in further activities combining science and arts, especially for students with reservations with science and a higher satisfaction level.

3. Learning Objectives

3.1 Domain specific objectives

The main objective of this approach is to give the opportunity to high school students to

- Promote the learning of scientific concepts in the domain of planetary formation and volcanism
- Get students interested in science and research
- Encourage students to acquire knowledge through enquiry-based learning
- Encourage students to use this knowledge for artistic expression e.g. theatre play, painting or video production
- Promote contact between students and professionals e.g. researchers and artists)
- Engage parents and the general public into schools' happenings and events

3.2 General skills objectives

Students' general skills objectives are:

- Develop creative skills
- Use practical skills to do experiments and relate
- Work in teams

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to high school students to acquire knowledge of scientific concepts not being taught in schools that deeply. In a second step they are encouraged to dramatize their knowledge in theatrical play or any other artistic expression of their choice. In this way, students learn science in a creative way.

The Planetary Evolution demonstrator aims at the enhancement of the students' cognitive involvement, their representation of scientific content using their cognitive processes, the students' sensorimotor involvement using their bodies or gestures, their emotional involvement, social interaction and communication between them, the use of past experiences and creation of new ones based on sociopolitical and historical framework and on beliefs and behaviors, their brain, body and emotion coordination and finally the holistic use of their personality and motives.

The main goal of the specific demonstrator therefore is to incorporate a series of activities that allow students to create an engaging learning environment in the classroom. Students will be given the opportunity to enquire and learn how our planetary system formed and how this legacy continues to influence processes in our earth. They will acquire basic concepts and principles guiding the field of magnetism, volcanoes etc. beyond the school curriculum by utilising artistic expression.

The demonstrator involves a set of interactive activities guided by the principles of the IBSE approach that aspires to engage students in an authentic scientific discovery process. Students will be challenged to project the acquired knowledge and scientific concepts through dramatization activities.

Part I: Workshop

Segment 1 (90 minutes)

- Welcome + Introductions (5 minutes) All participants gather for a welcome session. The program director explains the sequence of the day's activities.
- Icebreaker activity (10 minutes)
- Learning Modules (45 minutes) Each learning module is intended to deliver an information packet to the participants through visual and/or performance art, hands-on experimentation, and play. Each module begins with a short video that explains the broad context of the information packet (i.e., formation of the Solar System, volcanic processes, planetary magnetism). After answering any questions, the module leader then orientates participants to the specific module activity, as described in detail below.

Learning Module 1 – From Dust to Planets

Learning objective	*Location*	*Materials/Preparation*

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Planets formed in the early stage of Solar System evolution through the accretion of dust into small planetesimals, which further accreted into larger planetary embryos, and then protoplanets, and finally the rocky bodies of the inner Solar System that we have today (Mercury, Venus, Earth, Mars).	Large open space, such as a gym or outdoors	• Video, "Formation of the Solar System"

Students watch a video of how the Solar System formed up until the formation of the protoplanetary disk. We then continue with a physical activity in a large open space, preferably a gymnasium or outdoors. One volunteer participant is designated as the *proto-Sun*. Participants are explained that the Sun contributes >99% of the mass of a real Solar System, but that we've shrunk our "human proto-Sun" down by many orders of magnitude. The rest of the participants are designated as *dust particles*. The proto-Sun and dust particles are individually instructed on their roles and responsibilities.

The dust particles are instructed to walk clockwise around the proto-Sun until the proto-Sun loudly calls the action word, "ACCRETE!", at which point, each dust particle must quickly link arms with the closest other dust particle, essentially doubling in size. The module leader informs that the dust particles have become *planetesimals*. Planetesimal pairs continue to walk clockwise around the proto-Sun until the second "ACCRETE!" is called. Each planetesimal (i.e., consisting of two participants) must then quickly link arms with the next closest planetesimal, forming a tight outward-facing circle. The module leader informs that the planetesimals have become *planetary embryos*. The process repeats a third time, leading to the accretion of eight-member groups, which the module leader informs are called *protoplanets*, consisting of approximately eight participants. This process continues until the entire group has accreted into a single planet.

Learning Module 2 – Magma and Volcanic Eruptions

Learning objective	*Location*	*Materials/Preparation*
During accretion, the terrestrial planets underwent large-scale melting, or global magma ocean episodes, that allowed the formation of planetary cores. In modern times, volcanoes continue to release heat from the deep interior of cooling planetary	Indoors (classroom) -------- The liquid nitrogen volcano demonstration (optional but recommended) must be performed in an open and outdoor setting, such as an empty parking lot or field.	• Video, "Volcanos of the Solar System" • Large demonstration table • Large clear plastic cups • Plastic straws • Clear red dish soap • Clear honey or golden syrup, whichever is more viscous • Water dyed red with food coloring

bodies, such as the Earth as well as the Moon and Mars in their early histories, in the form of magma (also called lava or molten rock) and gas. The behavior of magmas depends largely on its composition, which influences gas solubility. Magmas with high gas solubility are highly explosive (e.g., Mount St. Helens or Mt. Etna), while magmas with low gas solubility are much less explosive (e.g., Hawaii).		• Baking soda • Vinegar • Sand • 2 L bottle Diet Coke • Mentos (regular) • Volcanic eruption image packet* Please see further instructions for liquid nitrogen volcano demonstration. If not possible, a video of the liquid nitrogen volcano should be shown.

Participants watch a short video demonstrating the role of magmatism and volcanic activity in the evolution of the Earth, Moon, and Mars – from the early global magma ocean stage, which facilitated the physical and chemical segregation of the terrestrial planets into a layered structure of core, mantle, and crust, to the ongoing volcanic activity that releases tremendous amounts of heat along spreading centers of mid-ocean ridges, as well as in subduction zones and oceanic islands (i.e., Hawaii).

We then proceed to a series of experiments and demonstrations on the diversity of magmatic behavior, particularly how viscosity (i.e., thickness) relates to magmatic composition, which influences gas solubility and thus explosivity. The module leader shows three 'lavas' in clear plastic cups. Each cup contains a different liquid: (1) water; (2) dish soap; (3) honey or syrup. All three have been dyed red using food coloring. Participants are instructed to investigate the lavas, by stirring and blowing bubbles using provided straws, and describe their differences. Participants are prompted to guess which lavas will be most/least explosive and provide an explanation.

The module leader then proceeds to sequentially demonstrate three different eruption types (i.e., weak to high explosivity). These include the (1) baking soda/vinegar volcano, (2) Coke/Mentos volcano, and (3) liquid nitrogen volcano. If the latter is not possible, participants should watch a video.

Learning Module 3 – Planetary Magnetic Fields

Learning objective	*Location*	*Materials/Preparation*
Heat released from planetary interiors drives convection in their liquid metal cores, which generates a magnetic field. Planets, as a whole, therefore behave as magnets. Magnetic material, such as iron-bearing minerals crystallizing in a magma, orient according to magnetic field lines.	Indoors (classroom)	• Videos, "Planetary Magnetism" and "Reconstructing Pangaea" • Large transparent board or glass • Large bar magnet labeled north and south • Metal filings • If possible, a sample of crystalline magnetite or cup of magnetite-bearing beach sand

Participants watch a short video on the fundamentals of magnetism and how planets behave like magnets due to convection of liquid metal in their deep interior cores, and that common magnetic minerals, particularly iron-bearing magnetite (Fe_3O_4), align their magnetic domains (i.e., miniature compasses within the mineral's electronic structure) to the planetary magnetic field during crystallization. If available, a crystalline magnetite sample and/or magnetite-bearing sand are displayed.

Participants then continue with a hands-on magnets activity. A transparent board is positioned atop a flat ledge, such as a stack of books, and metal filings are placed atop the board. A volunteer participant is instructed to place the bar magnet below the glass plate and the metal filings orient into magnetic field lines. The magnet can be moved and the field lines will follow and reform.

Participants are asked to describe the shape of the field lines along different parts of the magnetic field. Ultimately, participants should identify that field lines near the magnetic equator (i.e., magnet middle) are parallel to the magnetic, while those near the poles curve outwards. The module leader explains that magnetic minerals behaves similarly; if crystallized near the equator, their domains are oriented parallel to the surface, while if crystallized near the poles, their domains are inclined. The video, "Reconstructing Pangaea" is shown to demonstrate how the paleomagnetic record of magnetic minerals on Earth has been used to trace the dramatic movement of tectonic plates and evolution of continents over several hundreds of millions of years of Earth history.

Interpretation and Sharing (30 minutes)

Participants are given paper and pencils and instructed to work individually for 10–15 minutes to construct a framework for *creative response* (e.g., theatrical play, music, dance, visual arts) to demonstrate their learning. Participants are encouraged to develop a performance- and/or arts-based concept that broadly elucidates the learned scientific concepts to a generalized audience (e.g., younger siblings or classmates). Individual work time at this stage—as opposed to group work—allows all participants to develop a unique idea, such that more extroverted participants do not silence or overtake quieter or more introverted participants.

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Upon conclusion of this activity, each participant presents a general overview of their concept to the group. The project director assigns a simple summary title, if one is not given, for each presented concept on a large piece of paper or whiteboard. Once all concepts have been proposed, participants vote on the concept they would most prefer to develop and perform as a group. If participants cannot decide upon a single topic (i.e., half the group desires one concept while the other half prefers another), the program director should decide if resources are sufficient to pursue and develop more than one concept.

Break Participants will be served snacks and beverages.

Workshop Segment 2 (90 minutes)

- Group Development of Creative Response Project (45 minutes)
Upon selection of a creative response for development, participants brainstorm as a group on the contents of the project. For the first 5–10 minutes, classroom aides (e.g., teachers, program director) should refrain from making suggestions or asking questions, and should allow participants to freely discuss the project goals as independent artists/creators. Ultimately, the program director will guide the participants to identify and assign roles and responsibilities, such as script-writing, set and/or costume design, etc.. The participant or participants from whom the creative response project(s) was selected can be assigned the role of youth project director(s), with responsibilities of overseeing the full project alongside the project director, unless they do not wish to accept this position. Alternatively, a group of youth directors can be identified.
- Task/Role-Oriented Development of Creative Response Project (30 minutes)
All participants should have clearly defined roles ("creative task groups"), while simultaneously allowing for changes to be made under modest instruction of the project directors. Participants use the remaining time to strategize how to complete the goals of their creative task group. This may include designation of script- and/or lyric-writing assignments, development of costume and/or set ideas, etc.
- Sharing (10 minutes) To wrap up the first day, all participants join together to report to the group the progress/goals/objectives of each creative task group. Ongoing discussion topics and/or issues that require further exploration are recorded on a large piece of paper by the project or youth project director. Each creative task group should have a moderately clear idea of the logistics to achieve individual responsibilities (e.g., costume/set materials, instruments needed, etc.). If possible at this stage, a working title of the creative response should be identified or modified from the initial classification.

Workshop Conclusion (5 minutes)
Participants watch concluding video, "Symphony of Science," and are presented with a certificate of participation.

Part II: Work Sessions and Rehearsals

(2-hr meeting/rehearsal, once per week for 4–6 weeks)

Participants meet to discuss, work on, and rehearse their creative response. Additional resources (illustrated textbooks, popular science journals, YouTube videos) are obtained if necessary. Whenever possible, classroom aides should yield autonomy to the youth director or group of youth directors so that the final performance truly is a participant-led creation.

Performance and Recording The final performance(s) can be held in a classroom, auditorium, public setting (e.g., library, town hall, city and/or shopping center, etc.). If possible, the performance should be video and audio recorded for further dissemination.

If possible, a group photo should be taken upon completion of the program and professionally framed, including the title of the creative response project and names of its participants. This can serve as a physical memento of the participants' science-inspired creativity and performance.

4.2 Student needs addressed

The Planetary Evolution project includes the development of theatrical scenarios which are performed by the students and are in accordance with their interests and cognitive load. Students develop research questions, identify, investigate and experiment on various scenarios and scripts and construct knowledge under guidance of a scientist and teachers with creative concepts always involved during this process. The topic for the development of the theatrical play is selected by the students in a vote. This freedom of the topic selection is a challenging factor for students in order to get immersed in active investigations of scientific issues, and be engaged in collaborative discourse and creation. As a result, students manage to constructively build on each other's ideas, enhance their learning of scientific concepts, co-create and perform theatrical plays. The co-creation engages them in meaningful activities in authentic environments and the theatrical performance helps them learn end express scientific concepts using their body, gestures, etc.. Furthermore, collaborative learning is supported through Embodied Learning, which facilitates communication among students. Students' creativity and imagination is also evident in this demonstrator.

5. Learning Activities & Effective Learning Environments

Science topic: Planetary Evolution Relevance to national curriculum: limited Class information Year Group: 9th grade Age range: 13-15 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) *Where will the learning take place? School* *On site or off site? On site* *In several spaces? (e.g. science laboratory, drama space etc), or one?* Open space (gym), outdoors, classrooms *Health and Safety implications?* In some of the experiments special safety precautions apply. Teachers have to take adequate measures *Technology?* Beamer, pinboard, transparent wall, materials for experiments, costumes *Teacher support?* Yes. To encourage and help if necessary. Make sure that safety rules are obeyed. Organize rehearsals and performance
Prior pupil knowledge none	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will - Watch introductory videos which explain basic knowledge - Learn basic concepts by using artistic expression - Learn detailed concepts by enquiry based experiments - Present their knowledge in an artistic way to other students or an audience of parents, local community etc.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Individual with SMQ-II questionnaire pre and post. Additional knowledge pre and post test with a multiple choice questionnaire	*How can the activities be adapted to the needs of individual pupils?* Since there are no specific needs for the students to take part in this intervention, all students will benefit from it. Yet different capabilities of students can be taken into account by forming groups of similar abilities.	**Science terminology:** Geology, physics, astronomy, volcanoes, magnetism, planets **Arts terminology:** Ad-hoc-performances, creative arts, music, theatre

Session Objectives: Students will learn how planets formed, how volcanoes erupt and how magnetism works – through an approach combining video introduction, enquiry based experimentation, performances and artistic expression.

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Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with information given by introductory videos and through dialogue Build interest in scientific topics as well on the process of research Get to know the variety of interdisciplinary approaches in science Find similarities in every day phenomena	The scientist/teacher introduces the aim in a video in order to involve students to the specific scientific topic. He tries to attract the students' attention by eliciting students' relevant questions	Ice-breaker activities

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students collaborate in finding information about the topics in the specific domain.	Ensures that all students have access to information about the scientific topic, either through the internet or through printed materials. Coordinates the group of students. Ensures that the search results will be relevant to the topic that is selected.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyze information about history of the earth, compare them with their experiments and discuss the results with Phase 2 in mind	Acts as a facilitator of the process. Coordinates the discussions among students and coordinates the students to improvise and create first creative ideas for presentation.	

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students discuss and explain how scientists achieved their knowledge about the earth´s history	Acts as a facilitator of the process Identifies possible misconceptions	Students construct a framework for creative response (e.g., theatrical play, music, dance, visual arts) to demonstrate their learning
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students find connections between knowledge they learned from the videos, in the experiments and in their artistic expression	Allows room and enhances connectivism with other disciplines, such as arts, theatre and music. Coordinates and encourages the groups of students.	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students and groups communicate their findings amongst each other and develop ways to communicate to teachers, parents etc by using arts	Arranges a final rehearsal of the students to the venue of the final event. Coordinates the final science performance of the students.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect on the inquiry process and their learning while developing their artistic expression. The implementation ends with a theatre performance.	Discusses with the students what went well and what did not in the implementation of the final theatrical performance of students. Evaluates whether all students were	Students can use their knowledge to for a storyline of a dramatic scene Interdisciplinary activities (science and art activities) that include the creation of the

			involved in the creative inquiry process and fills an observation form provided by the organizers, which helps in the description and evaluation of the whole inquiry procedure (meaning making of scientific concepts, participation of students, inquiry learning procedure, embodied learning etc.)	final theatrical script, background music, scenery and costumes, choreography, potential video editing etc.

6. Additional Information

If you are interested in the CREATIONS´ approach you find more information on the website www.creations-project.eu.

Open Discovery Space Platform (http://portal.opendiscoveryspace.eu/creations) is an online platform where teachers and students have the opportunity to share their opinions and their educational resources for this and all other CREATIONS demonstrators.

CREATIONS project is also active on Scientix portal, the European platform for STEM teaching. If you are interested in STEM related information or if you are planning a collaboration with the CREATIONS project (implementation of demonstrators, teacher workshops etc.) you can contact your national ambassadors or the CREATIONS project partners.

7. Assessment

Both quantitative and qualitative data are required to assess students' and teachers' cognitive and creative development through the implementation of the Demonstrator. For quantitative assessment we recommend the use of the 'Science Motivation Questionnaire II (SMQ-II)'[38] (Glynn, et al., 2011; Maximiliane, Schumm, Bogner, 2016) that is addressed to students and the 'VALNET' questionnaire addressed to teachers.

Additionally we will measure the potential change in knowledge, pre- and post-intervention. For this purpose, we are developing a multiple-choice questionnaire with ca. 15 questions about the subject domain (planetary formation, Earth magnetism, volcanology) and ca. 3-5 possible answers.

Pre- and post-test questionnaire

(1) Which of the following is NOT a terrestrial planet?
   - A. Earth
   - B. Mars
   - C. Saturn
   - D. Mercury

(2) How did the terrestrial planets form?
   - A. A large single planet broke into smaller bodies that formed their own orbits around the Sun.
   - B. Dust particles clumped together to form sequentially larger bodies.
   - C. They were pulled into the Solar System from another star due to the Sun's immense gravity.
   - D. All of the above

(3) Which of the following is correct?
   - A. Our Solar System is the only place where planets are found in the universe.
   - B. The Earth is located at the centre of the Solar System but not the centre of the Milky Way.
   - C. The Sun is roughly twice as large as Jupiter.
   - D. Some planets within our Solar System are rocky while others are mostly gas.

(4) What is a planetesimal?
   - A. A small early-formed Solar System object that accreted to form planetary embryos.
   - B. This is the technical term for a small rocky moon that orbits a planet.
   - C. A planet made mostly of ice and gas instead of rock.
   - D. None of the above

(5) Read the following statements and select the combination for which all statements are <u>correct</u>.
   - i. Geologists study the origin, evolution, structure of planets, as well as the events and processes occurring both today and in the past.

[38] 2011 Shawn M. Glynn, University of Georgia, USA http://www.coe.uga.edu/smq/

ii. Structures on the Earth's surface can change dramatically over very long periods of time.
iii. Volcanoes erupt due to intense solar radiation and O-zone deterioration.
iv. Scientists study samples collected from the Earth's mantle and core to better understand their structure and chemistry.

A. i, ii, and iv, but not iii
B. i, ii, and iii, but not iv
C. i and ii only
D. All of the above

(6) The mass of the Sun contributes approximately _______ of the total mass of the Solar System.
A. 75%
B. 99%
C. 25%
D. 60%

(7) Select the correct sentence below.
A. Earth is the only planet with volcanoes.
B. Volcanoes can form underwater.
C. There is no record of ancient volcanoes because volcanic ash is easily transported by wind.
D. The Moon currently has active volcanoes.

(8) Which of the following have the strongest influence on volcanic explosivity?
A. Amount of lava
B. Amount of gas dissolved in the lava
C. Size of the volcano
D. Age of the volcano

(9) Which of the following is <u>not</u> an igneous rock?
A. Basalt
B. Granite
C. Sandstone
D. Obsidian

(10) Which physical property does viscosity describe?
A. The content of volcanic gases present within a lava
B. Average rock hardness
C. The amount of energy required to melt a rock
D. How easily a material flows

(11) A high-viscosity lava can dissolve _______ quantities of gas.
A. high
B. low
C. zero
D. infinite

(12) Which of the following is the most common volcanic gas?
A. Water
B. Carbon dioxide

C. Carbon monoxide
D. Sulfuric acid

(13) Read the following statements and select the combination for which all statements are correct.

i. At times during its formation, the Earth was completely covered by magma.
ii. The formation of volcanoes is a common way that heat is released from a deep planetary interior.
iii. Meteorite impacts can cause melting of a planetary surface.
iv. A volcano's explosivity is largely controlled by its composition.

A. i, ii, and iv, but not iii
B. ii, iii, and iv, but not i
C. i and iv only
D. All of the above

(14) Does the Earth currently have a magnetic field?

A. Yes
B. No
C. Sometimes, but the magnetic field orientation changes
D. No, but it did in the past

(15) Which of the following is correct?

A. Planetary magnetism is what keeps things connected to the surface and not floating into the atmosphere.
B. A magnetic field shields a planet from all solar radiation.
C. A record of past magnetic activity on Earth is preserved in the orientation of iron-bearing minerals.
D. Planetary magnetism was discovered in the last fifty years.

(16) Which of the following correctly describes the Earth's interior?

A. The crust, mantle, and core are all solid.
B. The crust and mantle are solid, but the core is a liquid.
C. The crust and core are solid, but the mantle is a liquid.
D. The crust and portions of the mantle and core are solid.

(17) Which of the following does not provide information about the Earth's core?

A. Seismic waves generated by earthquakes
B. Meteorites
C. Laboratory experiments
D. Samples collected from the core during deep drilling operations

(18) Read the following statements and select the combination for which all statements are correct.

i. Magnetic field lines are parallel to the Earth's surface at the equator, but perpendicular to the Earth's surface at the poles.
ii. Magnetic field lines are parallel to the Earth's surface at the poles, but perpendicular to the Earth's surface at the equator.
iii. The Earth's core formed at the centre of the planet because metal is denser than rock.

iv. Scientists attribute the Earth's magnetic field largely to convection in the Earth's mantle.

A. i and iii only
B. i and iv only
C. i, iii, and iv
D. ii, iii, and iv

(19) The Earth has the following volumetric proportions:

A. ~10% crust, ~50% mantle, ~40% core
B. <1% crust, ~80% mantle, ~20% core
C. ~5% crust, ~45% mantle, ~50% core
D. ~40% crust, ~40% mantle, ~20% core

(20) What was Pangaea?

A. An early life form that evolved into modern fish
B. A formerly inhabited Greek island that is now underwater
C. The common name for the hypothesis that the Moon formed from a giant impact with the Earth
D. A former supercontinent

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8. Possible Extension

Demonstrator could be extended by

- Less/more/other disciplines and topics.
- Painting arts instead of theatre

One possible extension is engaging parents and local community to the preparation of the theatrical scripts, costumes, etc.. Furthermore, by encouraging teachers and students from other countries (for example cross border cooperation with dutch schools) to participate to the project, it could become a large scale international activity.

Another extension, which meanwhile has been implemented successfully, is the reduction of the entire process to half a day. The students have about one hour time for the creative conversion into a short performance, video or painting.

9. References

- Videos:
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D3.2.67 Text Adventure Game

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Bernd Müller, Alexander Struck	
Code:	D 3.2.67.	**Contributors:**	
Version & Date:	V1 , 20/04/2018	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Biology, Chemistry and other scientific domains

1.2 Type of Activity

The specific activity is a combination of
- School based with lager parts of homework
- a local activity

1.3 Duration

1h for the introduction, up to 4 weeks for the realization, 3h for the presentation

1.4 Setting (formal / informal learning)

Informal. Students explore domain knowledge and skills for realization completely by themselves.

Formal and Informal learning settings are
School
Homework

1.5 Effective Learning Environment

Dialogic Space / argumentation
Time/space to develop a storyline of a science text adventure game

2. Rational of the Activity / Educational Approach

2.1 Challenge

New teaching methods have to be developed, allowing students to take a more active role on science learning. One of these methods is the use of serious games (gamification), which aims to motivate students with challenges, fostering practice, providing immediate feedback and enabling them to learn science-related topics in a more playful way (National Research Council, 2011).
The so called game-based learning or gamification is a didactic methodology that is gaining significance in recent times (Durall et al., 2012). This learning methodology has demonstrated to support immersive and experiential learning, cognitive development and skill acquisition by students (Durall et al., 2012). In addition, Klopfer (2008) mentions that games can allow students to learn certain contents in a faster way than using traditional teaching methods. Wu et al. (2016) complement this belief adding that a number of studies support game-based learning since games can increase students' dedication to their studies and are more attractive than conventional instructional methods. Also gamification could lead to a more gender equal access to learning of science and new scientific careers.
According to Barab and Dede (2007), virtual science games help students to identify more with science and with learning processes related to them. This is due to the fact that learners consider that science education is more important and effective when communication technologies are applied. Furthermore, virtual science games can be used through different platforms, such as cell phones, tablets, computers, game consoles, etc. providing a variety of tools to engage students in learning science (National Research Council, 2011).

2.2 Added Value

The approach of a classical text adventure in combination with scientific domain knowledge encourages students to translate the knowledge into linguistic forms of expression. For example instead of mathematically describing physical effects, these are described here with words, which leads to a deeper understanding of what has been learned.

During the implementation, the students are free to pick up and implement any topics within the given domain. The students acquire their knowledge by themselves, without the support of the teacher.

The finished game can be played in class by the classmates and also by students of the following years. These students learn from the work of their predecessors and create their own game on a new topic. As a result, a pool of text adventures on a wide variety of topics is created over the years.

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3. Learning Objectives

3.1 Domain specific objectives

The domain specific objectives are:

- Get students interested in science and research through creating and playing text adventures
- Boost knowledge about the chosen science topic
- Better memorize the information presented in the game
- Reach a higher level of satisfaction for students who are usually less interested in scientific topics but can be activated by an arts approach
- Show that science, writing, playing can be combined in a creative way

3.2 General skills objectives

Students' general skills objectives are:

- Learn how to use software to create text adventures
- Develop skills of enquiry based learning
- Understanding scientific concepts and phenomena
- Learn how to communicate scientific concepts
- Discuss scientific concepts and approaches of realization groups
- Learn how to organize a project in sub-projects

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The students develop a text adventure game. The topic can be chosen by the students themselves, but it should be within the subject of the school year, e.g. mechanics, electricity, heat when it is in the physics domain. All other STEM subjects such as biology, mathematics, geography, history etc. are also suitable.

The implementation of the demonstrator is divided into four parts:

1. introduction of the project management together with the teacher in one school hour. The task is introduced as well as the software Twine, with which the text adventure is created. During the introduction groups of 4 students are formed, who develop a story together. The introduction specifies when the students should produce results.

2. After one week there should be a rough storyline with two challenges for the player, which are based on scientific concepts.

Examples:
… You're sitting in a car, driving over a cliff into the sea. The car sinks and is already almost completely under water ...
… XXXXXXXXX
In these examples the player has to type in how he can escape from this situation. In the first example a possible correct solution would be: … Open the windows of the car and let the water in … . A wrong solution would be: … Try to push open the doors …

3. In the following 3 weeks (longer periods are also possible) the students write the text for their adventure. The challenge is to tell an exciting story that draws the player into the action. In addition, the player should face challenges that can only be mastered with scientific knowledge. Answering correctly provides bonus points, a wrong answer costs lifes.

4. In a final event at school, the students play the adventures of their classmates. Whoever scores the most points gets a prize, and the students also choose the best adventure that also gets a prize.

Background: Text adventures were the first computer games ever. Its heyday was in the 1980's, a well-known representative is the 1977 adventure game Zork. Lately text adventures are enjoying some popularity again despite the great competition of games with 3D graphics, because even laymen can develop such a game very easily.

The Twine software, for example, which is recommended for this demonstrator, is suitable for this purpose. Twine is free of charge and easy to learn as it requires no programming skills for basic functionality. Twine is a simple editor that makes it very easy to write stories. Branches can be built into the storyline where the player has to choose an option. This can be an answer "right" or "wrong" or the entry of a number, for example as a solution to a previously set mathematical task. Or the player has to

find a way out of a threatening situation based on the application of physical knowledge - basically similar to the hero in the old TV series MacGyver.

4.2 Student needs addressed

Students don´t need any specific basic knowledge. A creative and collaborative learning environment should be provided as well as support by the teachers to answer questions regarding the scientific domain. Students need persistent assessment which is given by testing the game and by the members of each group.

5. Learning Activities & Effective Learning Environments

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: Every STEM-topic; physics is preferred in the first implementations (Relevance to national curriculum) Class information Age range: 15-17 Sex: both Pupil ability: The scenario allows space for pupils of various abilities to participate	Materials and Resources Printed questionnaires pre- and post-test Computer for every student, Twine-software Online resources for learning the usage of Twine Where will the learning take place? At school (classroom or meeting places), at home Health and Safety implications? none Technology? Computer and Twine-software Teacher support? Sometimes. To encourage and help if necessary
Prior pupil knowledge Normal computer skills (no programming skills needed)	

Individual session project objectives (What do you want pupils to know and understand by the end of the lesson?)

During this implementation, students will

- Listen to the introductory talk which explains the aim of the intervention
- Learn how to use Twine-software
- Develop a storyline and write an adventure
- Transfer specific STEM-knowledge into written text tasks

Assessment	**Differentiation**	**Key Concepts and Terminology**
Self assessment in groups and by classmates when playing the adventure Teacher has to make sure that Creations features are taken into account, especially dialogue, interdisciplinarity and immersion	*How can the activities be adapted to the needs of individual pupils?* If pupils aren´t capable of using (or don´t have) a computer they can join groups with other pupils. Within the group they can share tasks depending on individual capabilities.	Science terminology: Physics, chemistry, biology … (Can be expanded to most scientific fields) Arts terminology**:** Serious Gaming

Session Objectives: During this implementation, students will learn scientific knowledge, develop a storyline, communicate it as a text adventure, use Twine-software

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Chooses a scientific question in the given domain and gathers knowledge to solve it Engage with information given by an adventure game and through dialogue	Challenges students with questions and problems in the given domain Teacher divides students in groups and supports students with background information about the scientific domain	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students collaborate in finding challenges to be build in an adventure game	The teacher identifies possible misconceptions and helps to find tasks appropriate for the level of knowledge of the students	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students find the solutions for their self-chosen challenges/tasks		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students discuss and explain the scientists work in the light of gender related topics	Acts as a facilitator of the process	Students develop a storyline (text and sketch) for the adventure game which includes the scientific challenges
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Other students who play the games of their classmates have to master the challenges by using knowledge about scientific concepts	Acts as a facilitator of the process	Students are immersed in the game and have to "translate" the story backwards to scientific concepts

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Groups communicate explanations about the challenges	Assess students knowledge by evaluating the results of the game	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect on the inquiry process developing their game and the learning by playing the games of their classmates	Assess students understanding after finishing the game	Students can recapitulate the game they played by performing it as a short theatre play

6. Additional Information

If you are interested in the CREATIONS´ approach you find more information on the website www.creations-project.eu.

Open Discovery Space Platform (http://portal.opendiscoveryspace.eu/creations) is an online platform where teachers and students have the opportunity to share their opinions and their educational resources for this and all other CREATIONS demonstrators.

CREATIONS project is also active on Scientix portal, the European platform for STEM teaching. If you are interested in STEM related information or if you are planning a collaboration with the CREATIONS project (implementation of demonstrators, teacher workshops etc.) you can contact your national ambassadors or the CREATIONS project partners.

7. Assessment

Pre-evaluation phase
Two weeks before the start of the project, students are asked to answer the Science Motivation Questionnaire for students (SMQ II) with the open question. The total amount of time for this activity is 10 minutes.

After Intervention phase
After the intervention students are asked to fill in the states emotions (SE) questionnaire. After the intervention the researcher asks students to give some comments about the activity.

Post-evaluation phase
To measure perceptions and generic learning outcomes from the intervention, a certain period of time should be considered in between the pre- and post-evaluation. Due to this, the post-evaluation can be done after 14 days. First, students answer the SMQ II questionnaire and then answer questions about challenges in the games to find out if they remember the scientific concepts.

During the implementation process a self-assessment through collaboration is taking place. Also the adventure game gives immediate response if an answer is right or wrong by collecting bonus points or loosing lifes.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

Demonstrator could be extended by using it for other disciplines and topics rather than physics.

9. References

Twine Software

Download: http://twinery.org

User guides: http://www.adamhammond.com/twineguide

https://twinery.org/wiki/twine2:guide

Five best Twine adventures: https://www.giga.de/downloads/twine/gallery/text-adventures-die-5-besten-twine-abenteuer-fuer-lesefreunde

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Randler, C., Hummel, E., Glaeser-Zikuda, M., Vollmer, C., Bogner, F.X. & Mayring, Ph. (2011). Reliability and validation of a short scale to measure situational emotions in science education. International Journal of Environmental and Science Education, 6, 359-370

Wu, Y., Wu, Y. & Yu, S. (2016). An Augmented-Reality Interactive Card Game for Teaching Elementary School Students'. World Academy of Science, Engineering and Technology, International Science Index 109, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering, 10(1), 37 - 41. URL: http://waset.org/publications/10003259/an-augmented-reality-interactive-card-game-for-teaching-elementary-school-students

D3.2.68 Particle Physics Workshop

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Maria Pavlidou, Cristina Lazzeroni
Code:	D 3.2.68.	**Contributors:**	Lynne Long, Konstantinos Nikolopoulos
Version & Date:	**V4, 13 June 2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, creative design of particles.

1.2 Type of Activity

School or University based – national UK

1.3 Duration

2 hours to half day

1.4 Setting (formal / informal learning)

- Starting formal: introductory talk in classroom or lecture theatre (in school or at the University)
- Continuing informal: group work in classroom (in school or at the University)
- Activity's website: the work has been submitted to the Physics Education magazine of the Institute of Physics, with the title: "Particle Physics for Primary Schools – enthusing future Physicists" by Pavlidou Maria & Lazzeroni Cristina, Article reference: PED-100750

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** school community works together during the workshop; After the workshop schools can create fluffy toy-models of the particle families as a whole school project which can involve parents too.
- **Arts-based:** the design of the particles is a creative form of model making and it gives full freedom to the children to come up with their own idea of designing the particle and then making them.
- **Dialogic space / argumentation:** through questioning and dialog students are allowed to express their views regarding scientific research and explain their choices regarding their own particle design.
- **Visits to research centres (virtual/physical):** groups of students can visit the University of Birmingham and complete the workshop in the University premises. As part of this visit students will be given a tour of the campus and they will have the chance to speak to undergraduate students about university life.
-
- **Communication of scientific ideas to audience:** the workshop allows for the modern scientific ideas or particle physics to be shared with the young audiences (ages 8-13).

2. Rational of the Activity / Educational Approach

2.1 Challenge

(Description of the problem)

Young students hear on the news about the recent discoveries in the area of particle physics and this creates curiosity about the subject and a series of questions on the world of particles. This demonstrator addresses the need identified by teachers to introduce younger audiences to the world of particles in an easy and accessible way and satisfy and feed their curiosity at an early stage with the hope it will be sustained in future years.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The topic of particle physics is introduced via the curriculum only at the last two years of school study in the UK (ages 17-18). Younger audiences are equally curious about what matter is made of. Moreover, the similarity between human families and human interactions and particle families and particle interactions makes the concepts easy to understand and work with. Young students learn that in the world of particles there are "likes" and "dislikes" and family groups as in the human world.

Students learn modern concepts of particle physics and how particle physicists work to reveal the hidden structure of nature. This enhances their understanding of

- How science works
- The relative mass of particles
- How particle physicists "see" the seemingly invisible

It also allows them to experience science in a fun and less daunting way.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the workshop are:

- That matter is made up of elementary particles which are structured into larger particles, for example protons, neutrons and eventually atoms
- To understand that we cannot see the elementary particles (because they are too small) but particle physicists have discovered ways of detecting them
- To learn about the Large Hadron Collider (LHC) at CERN as a "motorway" where particles are accelerated to reach very high speeds
- To understand that particle physicists collide particles to reveal their inner structure
- To learn that through such experiments physicists found out 3 families of particles and the corresponding antimatter ones
- To appreciate some of the characteristics and properties of particles
- To have some idea of how particles interact to create new particles

3.2 General skills objectives

The main objectives are:

- To use creative and more familiar skills e.g. model making, playing games to help access science ideas
- To work with other students who they do not necessarily know how to reach a common target
- To demystify scientists and science in general
- To acquire some presentation skills to communicate a physics idea

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the demonstrator is to use a creative way to introduce the concepts of particle physics to a younger audience, satisfy their curiosity and show them that asking questions is an important part of science investigation.

4.2 Student needs addressed

The list includes:

- Satisfy curiosity
- Game playing and interaction with others (adults, specialists, other students)
- Engaging in fun group activities that has a clear educational purpose
- Freedom of expression to choose their preferred way of designing a particle model

5. Learning Activities & Effective Learning Environments

Science topic: Particle physics **(Relevance to national curriculum)** **Not in the curriculum for these ages.** **Class information** **Year Group: 4-9** **Age range: 8-13** **Sex: both** **Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) all inclusive**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** • **Introductory power point presentation on the world of particles** • **Materials for models (plasticine, plastic balls, decorations, pipe cleaners etc.)** • **Trump cards for happy families game** • **Teacher guidelines** • **Additional extra: Particle zoo fluffy toys** ***Where will the learning take place?*** **In school or at the University** ***On site or off site?*** **On site** ***In several spaces? (e.g. science laboratory, drama space etc), or one?*** **In a room that can facilitate lecture and group work** ***Health and Safety implications?*** **none** ***Technology?*** **Projector for power point presentation** ***Teacher support?*** **Yes. To encourage and help as necessary**

Prior pupil knowledge **none**

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***
During this scenario, students will
Session 1 (power point presentation with interactive demos): to introduce words, names, ideas around particle physics (1 hour)
Session 2 (happy families game): to familiarize themselves with the particle families (0.5 hour)
Session3 (particle model making): to be creative and aim to link characteristics and properties of particles with a chosen design of particle models (1 hour)
Session 4 (presentations): students present and explain their choices in particle model making (0.5 hour)
Session 2 is optional depending on time constraints or can be used as a follow up activity.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Questioning and dialog through all sessions as well as through final session 4	*How can the activities be adapted to the needs of individual pupils?* Students have the freedom of choice regarding their choices in particle model making. The only restrictions link to matter anti-matter student pairs.	**Science terminology:** **Particle physics, protons, neutrons, quarks, particle accelerator, CERN, leptons, bosons, matter, antimatter** **Arts terminology: model making**

Session Objectives:
During this scenario, students will deepen their understanding of scientific concepts using their creativity, imagination and freedom of expression.

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Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with teacher's questions. Watch power point presentation and demos.	Workshop leader will use challenging questions pictures and demos involving the students to attract the students' interest in the structure of matter and the principles of particle physics research.	**None at this stage**
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk,*	Students gain an insight into the particle scattering experiment using a demo with	Workshop leader will question students to ensure links between observations and	**None at this stage**

	immersion and play is crucial in *empowering* pupils to generate, question and discuss evidence.	muffin tray and balls of different sizes.	conclusions are understood.	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	N/A	N/A	N/A
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students make particle models and must explain the reasons for their choices and link these to properties and characteristics of particles.	Workshop leader facilitates and supports as required.	**Students use imagination and creativity in their design of particle model.**
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students explore the topic using connections with familiar concepts from other disciplines (e.g. family connections)	Workshop leader facilitates and supports as required	**Creativity in making analogies and connections between model making and particle characteristics**
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students present their work, after dialog and collaboration within the group, to an audience of students and teachers.	Workshop leader and teacher facilitates and supports as required	**Presentation and explanation of choices in model design**

Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students are questioned about the new acquired knowledge at the end of the workshop as well as to evaluate the process and learning experience.	Workshop leader initiates the evaluation through dialog and collects and acts on feedback.	**N/A**

6. Additional Information

The workshop has been adapted after the input of primary and secondary school teachers and is constantly being evaluated and adapted for different student groups.

Support and training of primary and secondary school teachers will be available. However, it is understood that many primary school teachers will be reluctant to become workshop leaders due to the specialised knowledge needed for this.

There is a plan for training and CPD which will be primarily aimed at outreach science officers of universities across the UK and interested teachers.

Below you can find detailed guidelines for teachers on the tasks of the Particle Physics Workshop.

Particle Physics Workshop: The World of Particles and their Interactions

Task 1: Happy Families game

Resources

One pack of 30 trump cards per group of 5 students maximum (from document "trump cards"). Each pack contains:

- 6 quarks,
- 6 anti-quarks
- 6 leptons
- 6 anti-leptons
- 6 bosons

How to play [1]

The aim of the game is to collect as many families (groups of 6 cards that belong to the same family) as possible.

1. Deal out all the cards so that every player gets an almost equal number of cards; this will depend on the number of players.
2. The dealer starts by asking another player for a card needed to complete a family.
3. If the other player has the card, they must give it to this player.
4. The player may continue asking for cards until they make a mistake.
5. When a mistake is made the player who was asked for their card takes their turn to request cards.
6. During the game, players can request and retake the cards taken from them in previous rounds.
7. When a player gathers a family they must put the 6 cards face down on the table in front of them.
8. The player who collects the most families is the winner.

Task 2: Make your own particle!

Resources

To make the standard model that includes matter and antimatter:

- 30 Plastic coloured balls
  - 12 must have the same colour for quarks and anti-quarks
  - 12 must have another colour for leptons and anti-leptons
  - 6 must have a third colour for bosons
    - http://www.theworks.co.uk/p/outdoor-toys/mega-box-of-balls/5021813115458
    - http://www.argos.co.uk/static/Product/partNumber/3665514.htm
- Coloured pencils for designing the particle before making it (must include the same variety of colours as the plastic balls available)
- Black thin permanent markers (for writing on the particles)
- A box of various decorations
  - http://www.theworks.co.uk/p/embellishments/bumper-craft-pack/5052089001978)
- 2kg of plasticine
  - http://www.easycomposites.co.uk/products/newplast-plasticine-modelling-clay.aspx
- Scales to measure 5 grams
- Sellotape (to close the particle once it is stuffed)

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- double-sided sellotape (to stick the features on the particle)
- Scissors and art knife for cutting the balls open
- Black and white card to be used for a feature that distinguishes matter (white) from antimatter (black)
- Top trump cards (30 in total) for designing the particles
- Worksheet "The world of particles with mass" for reference

Designing the particles

The whole class must decide what colour balls they will assign for each particle family i.e. quarks and anti-quarks one colour, leptons and anti-leptons another and finally bosons a third colour. Each student will make one particle from a total of 30 particles.

1. Teacher distributes trump cards, one per student.
2. Students look at the box of decorations to give them an idea of what is available.
3. They read the particle information on the trump card in order to get inspiration for their design.
4. They decide what they want their particle to look like.
   (a) For example: what will a strange particle look like?
   (b) What will a charm particle look like?
5. Students working on a particle-antiparticle pair must sit near each other because they will be making these decisions together, since their particles will be **identical** with the exception of one feature (e.g. hat, cape, base stand) which will be made in white card for the particle and in black card for the antiparticle.
6. Students draw the particle features they chose on the trump card.

Giving mass to the particles

Students take one of the plastic balls (the right colour) and read the information about the mass of the particle they are making, from the worksheet "The world of particles with mass". They will add mass to their particle by filling the ball with plasticine following the rules below:

- If the particle is "very light" they do not put any plasticine in it;
- If the particle is "light", they cut-open the ball along its waist and put 5 grams of plasticine inside it. Then they close the ball and stick it with sellotape;

- If the particle is "heavy", they cut-open the ball along its waist and half-fill it with plasticine (about 100g). Then they close the ball and stick it with sellotape;
- If the particle is "very heavy", they cut-open the ball along its waist and fill it up entirely with plasticine (about 200g). Then they close the ball and stick it with sellotape.

Adding features to the particles

1. Students look at the particle trump card and the design they chose.
2. They then take the features they have chosen from the box of decorations and use double-sided sellotape to stick these features on the ball-particle.
3. They add the final matter-antimatter feature in white or black card, which will distinguish the particle from its antiparticle.
4. Finally they write the name of the particle at its back (as seen below).

References

[1] Rules for happy families game taken from http://www.cartamundi.co.uk/en/spielregeln/gamerules/children

7. Assessment

Short term gained knowledge is assessed at the end of the workshop through questions and the student presentations.

Long term gained knowledge will be assessed through long term collaboration with specific teachers and schools.

Evaluation of the activity will also be completed using the evaluation procedures decided by the Creations project team.

8. Possible Extension

The long term evaluation of the sustained knowledge has not been tested yet. This could be added on a later stage of the project as extension.

In addition, in time, it is envisaged that the workshop will be accessible to schools from a wider area of the UK via the training that will be provided to other outreach officers of other UK universities.

9. References

Pending article: Physics Education "Particle Physics for Primary Schools – enthusing future Physicists" by Pavlidou Maria, Lazzeroni Cristina
Article reference: PED-100750

D3.2.69 Particle Physics Masterclass

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Sophy Palmer, Elizabeth Cunningham (STFC)
Code:	D 3.2.69.	**Contributors:**
Version & Date:	Version 1 26/05/2016	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics

1.2 Type of Activity

School, university or research facility based – Masterclass held at national laboratory

1.3 Duration

1 day (the programme of the day is modular, and different components can be run independently)

1.4 Setting (formal / informal learning)

Both formal and informal settings - formal lectures, informal tours in small groups, workshop activity in teams, opportunities for questions throughout.

1.5 Effective Learning Environment

Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation

- Students and teachers will take part in computer workshops, using MINERVA visualization and analysis package.

Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

- Students and teachers are encouraged to question and interact with scientists and engineers during the workshop, tour and informal lunch session.

Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.

- Students and teachers will use real LHC data in order to discover properties of the Higgs Boson.

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Visits to research centres (virtual/physical) aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

- Students and teachers will all have a guided tour around a particle accelerator, with a scientist or engineer working there.

Communication of scientific ideas to audience addressing the need to establish settings in which learners will be enhanced to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.); promoting this way a dual channel of communication: a) reflective processes (self-engagement for scientific consistency and verification) and b) explicit elaboration of scientific ideas through interaction and 'extroversion'.

- Students and teachers will have a series of lectures and take part in an interactive quiz.

Arts-based which addresses and enhances scientific interconnection of science with aspects of art

- Students will be encouraged to take reflective photographs throughout the day and submit their most inspiring/interesting photograph with a caption (via social media) into a masterclass photography competition.

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Particle physics and the work of the Large Hadron Collider are very inspirational topics and students are curious about the ongoing research. Often, though, teachers do not feel they have the knowledge and background to be able to answer their students' questions. The particle physics masterclass allows students, and teachers, to interact with the scientists and engineers working at the Large Hadron Collider, and gives them to opportunity to experience particle physics for themselves.

2.2 Added Value

The collaborative computer workshops use the MINERVA tool, which has been developed to help students learn more about the ATLAS experiment and particle physics at CERN. It is based on Atlantis, the event display used at ATLAS to visualise what happens in the detector. The aim of MINERVA is to give students a better understanding of how particle detectors work and the physics that they study. Currently, in MINERVA, students are able to study W and Z boson events by observing their decay products and apply this knowledge to search for the Higgs boson. By taking an inquiry based approach to finding the Higgs, this workshop enables students to experience what it is like to be a particle physics researcher.

The masterclasses give students the opportunity to interact with scientists and engineers in both formal and informal settings. During the tours and workshops students are in small groups and have the chance to question their guides and demonstrators.

Throughout the masterclass there are opportunities for the students and teachers to question the particle physicists working at CERN: both on the curriculum material and on further questions.

By asking the students to photograph what they find interesting throughout the day they will be able to express visually what has inspired them during the masterclass and capture a message that was important to them in a creative way.

By giving students the opportunity to visit some of the UK's particle accelerators, they will experience for themselves the size and scale of these facilities, learn more about the real-world impact of particle physics and accelerator research, and appreciate the fact that these facilities exist in the UK as well as at CERN.

The content of the masterclass is designed to link very closely to the English school curriculum in the final two years of school (age 16-18). This gives students and teachers more confidence to address and study these inspiring topics.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Particle Physics Masterclasses is to **inspire students with the cutting-edge and popular subject of particle physics.**

The domain specific objectives of the Particle Physics Masterclass are:

- Give students and teachers the chance to interact with particle physicists working with and at CERN
- Give students and teachers the chance to visit a large-scale particle accelerator in the UK (the ISIS Neutron and Muon Source, or Diamond Light Source), learning about the applications of particle physics
- Give students and teachers first-hand experience of 'big science' and allow them to appreciate both the scale of engineering involved and other applications of accelerator science
- Give students and teachers access to LHC data so that, working collaboratively within a group, they can discover the Higgs for themselves
- Assist teachers to build confidence in teaching relevant subjects

3.2 General skills objectives

The general skills objectives for the Particle Physics Masterclass are:

- Develop an understanding of scientific inquiry and careers
- Highlight the achievements of science and technology
- Understand the methodology that guides scientific investigation
- Value science and technology for its economic, social and cultural contribution to society
- Use photography to capture an image that is visually as well as scientifically interesting

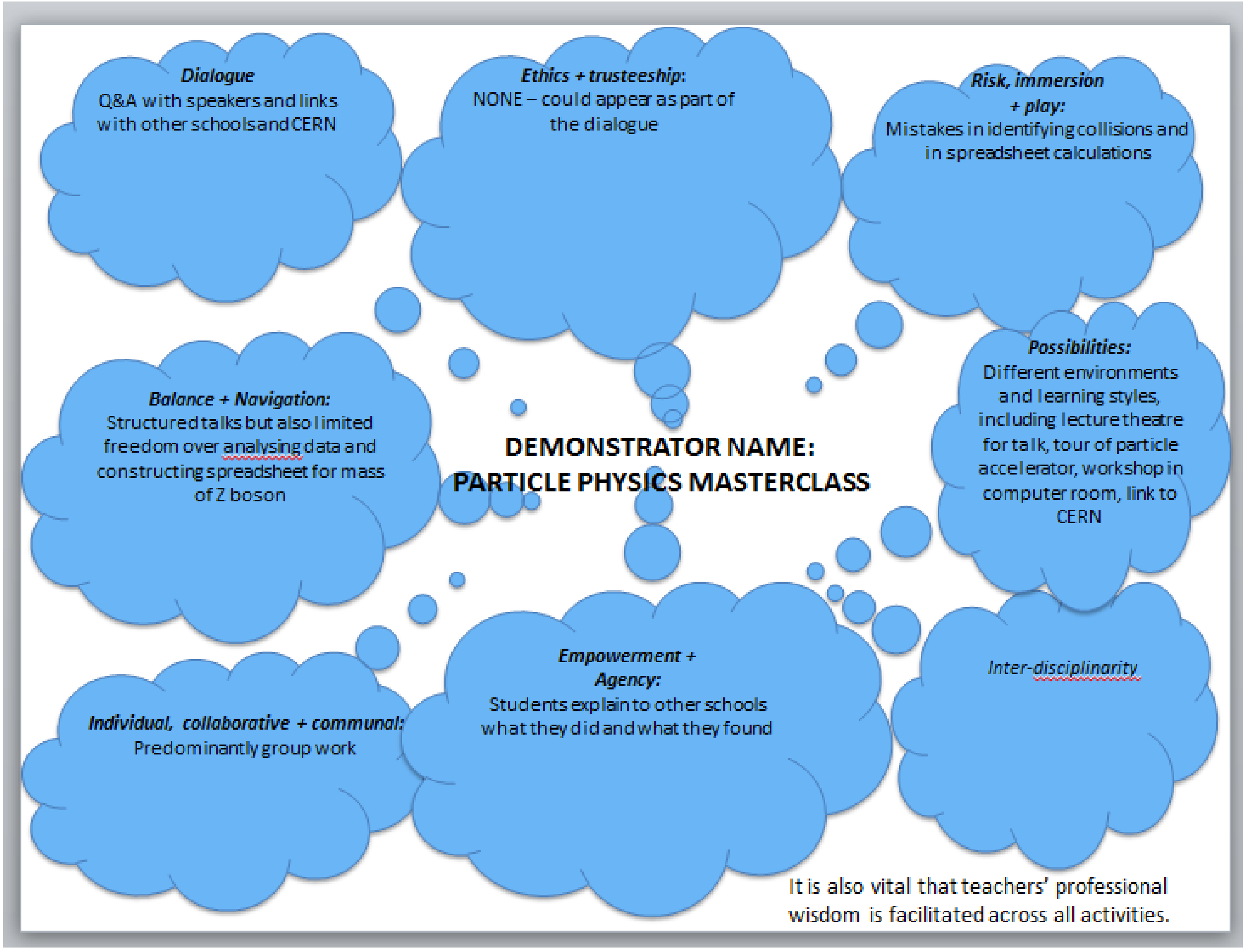
4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrators main aim is to engage 16-18 year old high school students studying physics and science teachers with particle physics through:

- Lectures and discussions with scientists and engineers (A very brief guide to accelerators, Fundamentals of particle physics, The Large Hadron Collider, Applications of accelerators)
- Hands on computer workshop using LHC data and the MINERVA tool
- Tour of particle accelerator in a small group
- Interactive quiz
- Photography competition

The masterclass improves the knowledge and confidence of both students and teachers in particle physics.



4.2 Student needs addressed

- Particle physics is a topic that interests and inspires, but which some teachers are not confident teaching.
- Using IBSE for the masterclass, allowing students to use real LHC data for themselves, acts to dispel the notion that 'particle physics isn't for me'.
- Gives students and teachers access to experts in what is considered to be a complicated field.
- Students are able to see how the direct applications of particle physics affect their lives.
- Students given the opportunity to highlight what is important to them through photography.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics (Relevance to national curriculum) Key component of A level syllabus (UK students, age 16-18) Class information Year Group: Year 12 & 13 (sixth form) Age range: 16-18 Sex: both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.printed questionnaires, teleconference, etc.) Lecture facilities, computers with internet access, evaluation questionnaires.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Masterclasses will be held at your local particle physics group. Some of the activities can be adapted for the classroom.* *Health and Safety implications? Knowledge of local fire and radiation procedures.* *Technology? Computer and internet access. Voting pads (for the quiz).* *Teacher support? Reference material.*
Prior pupil knowledge • Basic ICT skills • Commitment to attend the full day's event	

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will: Lectures: Learn about: the principles and applications of particle accelerators, fundamentals of the standard model, large hadron collider. Tour: Experience a real particle accelerator. Appreciation of the real world applications of particle physics – in engineering, chemistry and the life sciences as well as physics. Workshop: Empowerment from using real LHC data to solve a challenge and appreciation of collaborative nature of scientific research.		
Assessment Quiz to test their scientific knowledge and understanding. Student questionnaire. Teacher e-survey	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* All the students do the same activities, there are opportunities for students to ask questions and clarify points throughout the day.	**Key Concepts and Terminology** **Science terminology:** Maths, Particle and Accelerator physics. **Arts terminology:** **Photography**
Session Objectives: During this scenario, students will deepen their understanding of particle physics concepts and phenomena, through both formal and informal sessions. Masterclasses encompass the CREATIONS features of creativity: including dialogue; risk, immersion and play; possibilities; empowerment and agency; individual, collaborative and communal; balance and navigation.		
Learning activities in terms of CREATIONS Approach		

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students will engage with lecturers, tour guides and workshop leaders, creating a dialogue between students and scientists / engineers	Teachers will engage along with their students	
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will explore real data from the LHC	Teachers will explore real data from the LHC	

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will analyse the LHC data using MINERVA – based on ALAS event display. Students work collaboratively in teams – both within their school groups and, when combining data, across different schools.	Teachers will support their students throughout the analysis, alongside workshop leaders	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students use the data they have analysed to find the Higgs boson and determine its mass.	Teachers work alongside their students.	
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students use the knowledge they have learned in class and during the masterclass lectures to interrogate the data and their analysis of it.	Teachers encourage their students to connect their background information with the data and analysis work they have been undertaking.	

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	During the final phase of the MINERVA workshop, different teams of students come together to communicate their findings and work together to find a final result.	Teachers work alongside their students, encouraging them to contribute to the final group discussion.	
Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students will take part in an interactive quiz based on all aspects of the masterclass.	Teachers will take part in the quiz	**Students will be encouraged to take reflective photographs throughout**

			alongside their students	**the day and submit their most inspiring/ interesting photograph with a caption (via social media) into a masterclass photography competition.**

6. Additional Information

Further information can be found at:

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

7. Assessment

- Students and teachers will undertake an interactive quiz to gauge their learning from the masterclass.
- CREATIONS evaluation (student and teacher questionnaire) will be used to evaluate the masterclass.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

Students will be encouraged to explore the LHC for themselves by visiting

https://www.higgshunters.org/

so that they can become involved in further analysing LHC data, as part of the citizen science project.

Teachers can engage in further projects, such as:

- CERN@school
    - A project that brings technology from CERN into the classroom, allowing students to design and analyse their own experiments
    - https://cernatschool.web.cern.ch/
- HiSPARC
    - HiSPARC is a project in which secondary schools and academic institutions join forces and form a network to measure cosmic rays with extremely high energy.
    - http://www.birmingham.ac.uk/schools/physics/outreach/HiSPARCproject.aspx

These projects will allow teachers and their students to continue engaging with particle physics in an empowering, IBSE-based manner.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

Further information can be found at:

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

D3.2.70 Particle Physics Masterclass (extension)

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Maria Pavlidou, Sophy Palmer, Elizabeth Cunningham**	
Code:	D 3.2.70.	**Contributors: Cristina Lazzeroni, Kostas Nikolopoulos,**	
Version 2 & Date: 29 January 2018		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches.

School or University based: Particle Physics Masterclass

Local, national and international

1.3 Duration

half day (mini PPM) or full day (international PPM)

1.4 Setting (formal / informal learning)

Both formal and informal settings - formal lecture, informal tour of the campus in small groups, workshop activity in teams, opportunities for questions throughout.

1.5 Effective Learning Environment

Simulations aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation

- Students and teachers will take part in computer workshops, using MINERVA visualization and analysis package.

Dialogic space / argumentation aiming to engage students in argumentation and dialogic processes for a better insight into the nature of scientific enquiry and the ways in which scientists work

- Students and teachers are encouraged to question and interact with scientists during the workshop, tour and informal lunch session (only during international PPM).

Experimentation (Science laboratories and eScience applications) aiming to enhance students' physical and intellectual interaction with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.

- Students and teachers will use real LHC data in order to discover the Higgs Boson and specific properties of bosons.

Visits to research centres (virtual/physical) aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.

For the mini PPM there is no time to link with CERN. For the international PPM a link to CERN will allow students to discuss/question researchers on their findings.

Communication of scientific ideas to audience addressing the need to establish settings in which learners will be enhanced to externalize and elaborate on scientific concepts they have acquired while interacting with an audience (learners, teachers, scientists, parents, etc.); promoting this way a dual channel of communication: a) reflective processes (self-engagement for scientific consistency and verification) and b) explicit elaboration of scientific ideas through interaction and 'extroversion'.

For the international PPM, students and teachers will follow a series of lectures. For the mini PPM, students and teachers will hear one introductory lecture.

Art-based Learning Environment: students are inspired from the collision simulations to form artistic designs of particle collisions or particle interactions.

2. Rational of the Activity / Educational Approach

2.1 Challenge

The main challenge is that the teaching of particle physics can be dry and boring as there are no easy (or cheap) experiments to do in schools. An additional challenge is that the concepts are difficult to comprehend, as the world of particles is not visible.

Particle physics and the work of the Large Hadron Collider are very inspirational topics and students are curious about the ongoing research. Often, though, teachers do not feel they have the knowledge and background to be able to answer their students' questions. The particle physics masterclass allows students, and teachers, to interact with the scientists working at the Large Hadron Collider, and gives them to opportunity to experience particle physics for themselves.

2.2 Added Value

The collaborative computer workshops use the MINERVA tool, which has been developed to help students learn more about the ATLAS experiment and particle physics at CERN. It is based on Atlantis, the event display used at ATLAS to visualise what happens in the detector. The aim of MINERVA is to give students a better understanding of how particle detectors work and the physics that they study. Currently, in MINERVA, students are able to study W and Z boson events by observing their decay products and apply this knowledge to search for the Higgs boson. By taking an inquiry based approach to finding the Higgs, this workshop enables students to experience what it is like to be a particle physics researcher.

The masterclasses give students the opportunity to interact with scientists in both formal and informal settings. During the workshop students are in small groups and have the chance to question their guides and demonstrators.

Throughout the masterclass there are opportunities for the students and teachers to question the particle physicists working at CERN: both on the curriculum material and on further questions.

The content of the masterclass is designed to link very closely to the English school curriculum in the final two years of school (age 16-18). This gives students and teachers more confidence to address and study these inspiring topics.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Particle Physics Masterclasses is to **inspire students with the cutting-edge and popular subject of particle physics.**

The domain specific objectives of the Particle Physics Masterclass are:

- Give students and teachers the chance to interact and communicate with particle physicists working with and at CERN
- Give students and teachers access to LHC data so that, working collaboratively within a group, they can discover the Higgs for themselves as well as calculate characteristics of bosons
- Assist teachers to build confidence in teaching relevant subjects
- Allow students to learn the fundamental ideas in particle physics
- Allow students to analyse particle collisions in the same way these are analysed at CERN
- Show students how particle physicists cooperate and collaborate to solve the big fundamental questions

3.2 General skills objectives

The general skills objectives for the Particle Physics Masterclass are:

- Highlight the achievements of science and technology, as a direct result of the communication between teachers/students and particle physicists
- Understand the methodology that guides scientific investigation
- Value science and technology for its economic, social and cultural contribution to society
- Develop an understanding of scientific inquiry and careers

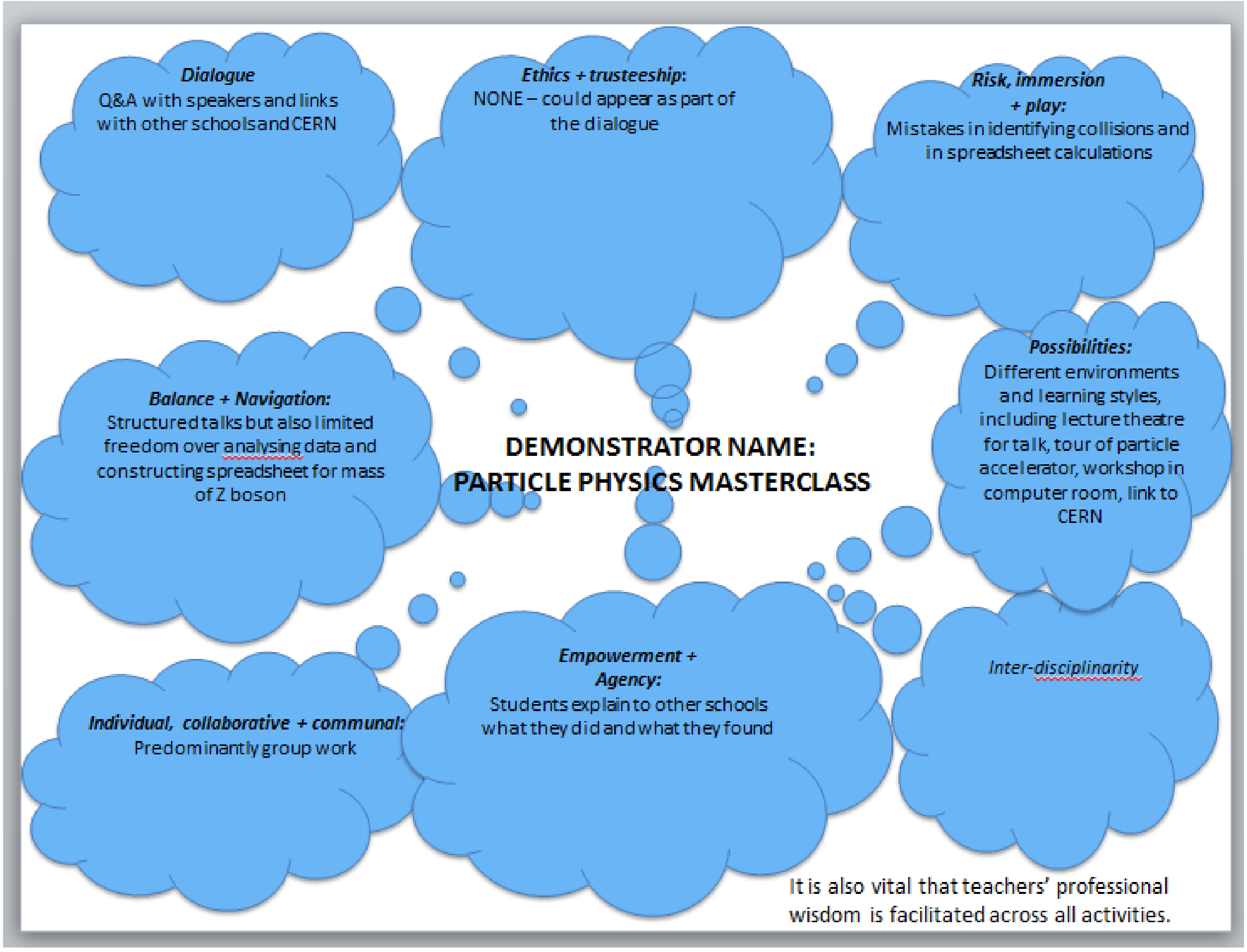
4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrators main aim is to engage 16-18 year old high school students studying physics and science teachers with particle physics through:

- Lectures and discussions with particle physicists
- Hands on computer workshop using LHC data and the MINERVA tool
- Link with CERN to discuss findings (only the international PPM)

The masterclass improves the knowledge and confidence of both students and teachers in particle physics.



4.2 Student needs addressed

- Particle physics is a topic that interests and inspires, but which some teachers are not confident teaching.
- Using IBSE for the masterclass, allowing students to use real LHC data for themselves, acts to dispel the notion that 'particle physics isn't for me'.
- Gives students and teachers access to experts in what is considered to be a complicated field.
- Students are able to understand how the direct applications of particle physics affect their lives.
- Student's need for enhanced learning is achieved
- Student's need in engaging with a difficult topic in a more accessible way is achieved

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics (Relevance to national curriculum) Key component of A level syllabus (UK students, age 16-18) Class information Year Group: Year 12 & 13 (sixth form) Age range: 16-18 Sex: both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.printed questionnaires, teleconference, etc.) Lecture facilities, computers with internet access, evaluation questionnaires.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Masterclasses will be held at the university or in various schools around the country.* *Health and Safety implications? Knowledge of local fire and radiation procedures.* *Technology? Computer and internet access.* *Teacher support? Reference material.*
Prior pupil knowledge • Basic ICT skills • Commitment to attend the full day's event (for International PPM)	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will: Lectures: Learn about: the principles and applications of particle accelerators, fundamentals of the standard model, large hadron collider. Workshop: Empowerment from using real LHC data to solve a challenge and appreciation of collaborative nature of scientific research. Link to CERN: discussion with other groups on the findings of the day		
Assessment During the workshop via discussion with researchers and from student and teacher questionnaire.	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* All the students do the same activities, there are opportunities for students to ask questions and clarify points throughout the day. Weaker students will analyse fewer collision events.	**Key Concepts and Terminology** **Science terminology:** Maths, Particle and Accelerator physics. **Arts terminology: visual arts, performing arts, freedom and choice of expression**

Session Objectives: During this scenario, students will deepen their understanding of particle physics concepts and phenomena, through both formal and informal sessions. Masterclasses encompass the CREATIONS features of creativity: including dialogue; risk, immersion and play; possibilities; empowerment and agency; individual, collaborative and communal; balance and navigation.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students will engage with lecturers and workshop leaders, creating a dialogue between students and researchers.	Teachers will engage along with their students.	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will explore real data from the LHC	Teachers will explore real data from the LHC	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will analyse the LHC data using MINERVA – based on ATLAS event display. Students work collaboratively in teams – both within their school groups and, when combining data, across different schools.	Teachers will support their students throughout the analysis, alongside workshop leaders	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students use the data they have analysed to find the Higgs boson and calculate the mass of the Z boson (or of another boson).	Teachers work alongside their students.	

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students use the knowledge they have learned in class and during the masterclass lectures to interrogate the data and their analysis of it.	Teachers encourage their students to connect their background information with the data and analysis work they have been undertaking.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	During the final phase of the MINERVA workshop, different teams of students come together to communicate their findings and work together to find a final result. This is done in length via the link to CERN	Teachers work alongside their students, encouraging them to contribute to the final group discussion.	Students will be asked to create, as an individual or as a group, an artistic piece, inspired by the masterclass which will be displayed in

				the Art Exhibition at the University of Birmingham during an Open Day.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students will take part in a questionnaire based on all aspects of the masterclass.	Teachers will take part in a questionnaire alongside their students	Students will be asked to create, as an individual or as a group, an artistic piece, inspired by the masterclass which will be displayed in the Art Exhibition at the University of Birmingham during an Open Day.

6. Additional Information

Further information can be found at:

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

http://www.birmingham.ac.uk/schools/physics/outreach/Secondary-Schools/particle-physics-masterclasses.aspx

7. Assessment

In all events we have used the standard CREATIONS evaluation questionnaire for students and teachers and this has been shared with the University of Bayreuth for analysis.

8. Possible Extension

Students will be encouraged to explore the LHC for themselves by visiting

https://www.higgshunters.org/

so that they can become involved in further analysing LHC data, as part of the citizen science project.

Teachers can engage in further projects, such as:

- CERN@school
    - A project that brings technology from CERN into the classroom, allowing students to design and analyse their own experiments
    - https://cernatschool.web.cern.ch/
- HiSPARC
    - HiSPARC is a project in which secondary schools and academic institutions join forces and form a network to measure cosmic rays with extremely high energy.

  http://www.birmingham.ac.uk/schools/physics/outreach/Secondary-Schools/HiSPARCproject.aspx

These projects will allow teachers and their students to continue engaging with particle physics in an empowering, IBSE-based manner.

9. References

http://atlas-minerva.web.cern.ch/atlas-minerva/

http://www.stfc.ac.uk/public-engagement/for-schools/schools-rutherford-appleton-laboratory/#ppm

http://physicsmasterclasses.org/

http://www.stfc.ac.uk/public-engagement/for-schools/particle-physics-for-you/particle-physics-masterclass-programme/

http://www.birmingham.ac.uk/schools/physics/outreach/Secondary-Schools/particle-physics-masterclasses.aspx

D3.2.71 Clocks and Gears

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Maria Pavlidou**
Code:	D 3.2.71.	**Contributors: Kostas Nikolopoulos**
Version & Date: v2, 24 Jan 2018		**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

How mechanical clocks use gears to control the speed of movement of the hands.

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches.

School or University based – local and national UK

1.3 Duration

2 hours up to half-day

1.4 Setting (formal / informal learning)

- Starting formal: introductory talk in classroom or lecture theatre (in school or at the University)
- Continuing informal: group work in classroom (in school or at the University)

1.5 Effective Learning Environment

- **Communities of practice (web-based/physical):** class works together during the workshop;
- **Arts-based:** the construction of the clocks uses creative skills and the ability of students to follow diagrammatic guidelines
- **Dialogic space / argumentation:** through questioning and dialog students are allowed to express their ideas on how ancient clocks work by looking at drawings and videos
- **Visits to research centres (virtual/physical):** groups of students can visit the University of Birmingham and complete the workshop in the University premises. As part of this visit students will be given a tour of the campus and they will have the chance to speak to undergraduate students about university life.
- **Communication of scientific ideas to audience:** the workshop allows students to understand how by using gears we can do mathematical calculations and control the speed of the hands. This can be extended to talk about astronomical clocks, the Antikythera Mechanism and how analysing

the gears of the Mechanism gives us detailed information about the astronomical knowledge of the ancient Greeks.

2. Rational of the Activity / Educational Approach

2.1 Challenge

The young generation lacks basic knowledge when it comes to simple machines such as levers, gears etc. To address this problem the current UK curriculum has introduced gears in year 5 of the primary science curriculum. Even so, students find difficult to calculate the relative motion of gears as they rotate around one another. For example, they find difficult to answer questions like "if gear A rotates x times then how many times gear B rotates by?" or "how many teeth should we make gear A and B with, if we want one of them to rotate twice as fast as the other?"

We hope that this workshop will deliver the topic of gears in a fun way and that it will also extend the knowledge of the students to understand how mechanical clocks use gears to control the movement of the hands and the mathematics that describes this. Using students as the "teeth" of gears, the relative motion of gears becomes exciting and fun and visually powerful and easy to understand.

2.2 Added Value

(Elaboration of the applied creative approaches and their purpose)

The workshop aims to extend the knowledge of the students to understand:

- how scientists use this knowledge to reveal the astronomical knowledge of ancient civilisations
- how groups of multi-disciplinary scientists are needed in analysing ancient machines
- how science and maths can help historians and archaeologists in their work.

The final stage of the clock-making workshop will allow students to learn the idea of instrument calibration by allowing them to alter the length of the clock pendulum and make the clock as accurate as possible.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the workshop are:

- To understand that clocks evolved through time, starting with simple water/sand clocks and slowly moving on to clocks with gears
- To understand that when an object rotates there are two speeds we can refer to, the linear and the angular
- To understand that two gears can be linked in two different ways: through the same axle or via a common point along their circumference
- To understand that the size of the gear (radius and number of teeth) is directly linked to how a gear will rotate relative to another
- To understand that the rotation of gears can be accurately described by mathematical equations
- To understand that the period of oscillation of a pendulum varies with its length and that this is used to calibrate the clock to work accurately
- To cooperate/collaborate in teams when creating a gear with their bodies
- To use dramatization and the movement of the human body to express mathematical calculations

3.2 General skills objectives

The general skills acquired or improved by the workshop are:

- To understand how equations can describe accurately the movement of objects
- To be able to understand how simple machines work by looking at their diagrams
- To improve dexterity by making a clock
- To understand how science can help reveal secrets from the past i.e. astronomical knowledge of ancient civilisations
- To understand how scientists work within a multi-disciplinary group where each member is an expert on their field

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the demonstrator is to use a creative way to introduce the concepts of gears and how they are used in mechanical clocks, to a younger audience.

The workshop is described below:

- Students listen to an interactive talk about the history of clock making and the mathematics of gears
- Students demonstrate what they learned by making gears using their bodies as the "teeth" of the gear. Teams of students rotate relative to each other as gears rotate relative to each other, and explain how many times one gear must rotate relative to the other, in order to reach the starting point.
- Students are given a kit to make a clock
- Students use the pendulum of the clock to investigate the relation between the length of its pendulum and the frequency of the ticking

4.2 Student needs addressed

The list includes:

- Satisfy curiosity on how clocks work
- Engaging in fun group activity (making clocks) that has a clear educational purpose
- Kinaesthetic approach to the learning of the concepts of gears and their equations (using their bodies as rotating gears)
- Understanding of how science works: the importance of using an accurate instrument for measuring time and how to achieve this

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

Introductory talk:

- Pictures of ancient clocks where students are asked to describe how they work e.g. hourglass, sundial etc.
- Diagrams of more complicated clocks e.g. Archimedes clock, where students are asked to figure out how the clock worked from the diagram given.
- Explanation of astronomical clocks and the Antikythera Mechanism
- The mathematics of gears with demonstrations on how gears link and how they rotate relative to one another

Human Gears:

Students are given the task to work in teams and create gears, holding hands in a circle. Each child represents one tooth of the gear. Two teams (two gears) stand side by side and the starting gear position is marked with the two initial children wearing visible hats and standing back to back. The team communicates and starts rotating to find out how the number of rotations relates to the number of teeth on the gear.

The examples become more complicated and the students are asked to demonstrate their own examples of gears.

Making a clock:

A simple clock kit is given and students follow diagrammatic instructions, working in pairs, to complete the clock. The clock has gears and other parts that they need to be put together in sequence in order for the clock to work well.

Using the clock's pendulum to understand physics:

On the final stage of the clock-making students are asked to calibrate their clock so that the tick tock sound lasts for 1 second. Students take measurements of the length of the pendulum and the period of oscillation. They discover the pattern: the longer the pendulum the longer the period. Finally they choose the best length to achieve a period of 1 second on their clock.

Science topic: **Gears** (Relevance to national curriculum) Class information Year Group: **5** Age range: **9-10** Sex: **both** Pupil Ability: e.g. (The scenario allows space for pupils of various abilities to participate) **all inclusive**	Materials and Resources *What do you need?* • **Introductory power point presentation on clocks and gears** • **Materials for making clocks** • **Stopclocks and rulers to calibrate clock** • **Paper, pencil to keep record of clock accuracy** *Where will the learning take place?* **In school or at the University** *On site or off site?* **On site** *In several spaces? (e.g. science laboratory, drama space etc), or one?* **In a room that can facilitate lecture and group work** *Health and Safety implications?* **Must have plenty of space when students emulate gears with body movements** *Technology?* **Projector for power point presentation** *Teacher support?* **Yes. To encourage and help as necessary**
Prior pupil knowledge **none**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

- Listen to the introductory talk and answer questions about how ancient clocks work by looking at diagrams, videos or photographs
- Engage in gear-rotation demonstrations using their bodies (groups of various student numbers make circles holding hands and rotate against each other)
- Construct a clock (in groups of two) by following guidelines which are given to them as a diagram only
- Calibrate their clock by altering the length of the pendulum of the clock and by taking measurements of the clock accuracy at different lengths

Assessment	**Differentiation**	**Key Concepts and Terminology**
Questioning and dialog through all sessions as well as through final session	*How can the activities be adapted to the needs of individual pupils?* The clock-making exercise will be the most challenging part of the workshop. Groups that struggle will get help but there will be a small number of groups that will take longer to complete the clock and therefore will not have time to calibrate it.	**Science terminology:** gears, mathematical equations, ratios, astronomical clocks, Antikythera Mechanism, calibration, accuracy **Arts terminology:** Model making, body-movement

Session Objectives: During this scenario, students will link the use of gears to mathematical calculations and how this controls the speed of rotation of clock hands.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students engage with teacher's questions, watch power point presentation and demos and try to interpret the movement of various mechanisms through drawings or videos.	Workshop leader will use challenging questions, pictures, drawings, videos and demos involving the students to attract the students' interest in the movement of	None at this stage

			gears and its link to mathematical equations.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students participate in body-simulation of rotating gears. They gain an insight into the movement of gears and the link between number of teeth and rotating speed.	Workshop leader will question students to ensure links between observations and conclusions are understood.	Group body movement to simulate rotating gears.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students think and decide how many classmates should there be in a circle in order for the circle to rotate faster/slower relative to another circle. Students test their hypothesis by trialling their ideas.	Workshop leader will pose questions that link the number of teeth in a gear (number of students in a circle) and its relation to the speed of rotation.	Group body movement to simulate rotating gears.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students will be asked to explain why is it that if the number of teeth in a gear doubles this results in the speed of rotation being halved etc.	Workshop leader will give help by asking them to think about the length of the circumference relative to the number of teeth.	None at this stage
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Discussion follows between workshop leader and students where the idea below is derived: that doubling the teeth doubles the circumference and therefore at the same time the speed will be halved.	Workshop leader drives the discussion to reach the conclusion that doubling the teeth doubles the circumference and therefore at the same time the speed will be halved.	None at this stage

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students choose a partner to work on constructing a clock.	Workshop leader emphasizes the importance of choosing a partner not based on friendship but based on skills that the first student does not have so that the team becomes stronger.	None at this stage
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students make a clock, in groups of 2, following diagrammatic instructions.	Workshop leader will help students as and if needed.	Model building.

6. Additional Information

The clock-making exercise uses the product:

https://www.amazon.co.uk/Tobar-Make-Your-Own-Clock/dp/B0039ZMZGK/ref=sr_1_6?ie=UTF8&qid=1470657253&sr=8-6&keywords=clock+making

7. Assessment

Short term gained knowledge is assessed throughout the workshop by posing questions. Examples include questions like: " how many teeth do we need on a gear to make it rotate three times as fast as this gear". Students have successfully answered such questions, giving evidence for the new knowledge they acquired.

The standard CREATIONS evaluation questionnaire has been used in all the clocks and gears events we have ran so far and this has been sent to the University of Bayreuth for analysis.

8. Possible Extension

After trialling this workshop we will re-evaluate the resources and decide on possible extensions or alterations.

9. References

The Antikythera Mechanism Research Project: http://www.antikythera-mechanism.gr/

Dave Goodchild's model of the Antikythera Mechanism: https://www.youtube.com/watch?v=Ke_wspU5748

Museum of the Ancient Greek Technology: http://kotsanas.com/gb/

D3.2.72. Neutrino Passoire

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Konstantinos Nikolopoulos, Mairi Pardalaki**
Code:	D 3.2.72.	**Contributors:**	M. Pavlidou
Version & Date:	**V2 28/05/2018**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1. Subject Domain

Particle Physics

1.2. Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).
Local activity.

1.3. Duration

2h to 1/2 day

1.4. Setting (formal / informal learning)

- Informal setting: the dance class room.

1.5. Effective Learning Environment

- Informal Learning Environment
- Arts-based: the discovery of the properties of the particles through dance is a creative approach to learning (Session 1). Watching a science-inspired performance and in the subsequent Q&A session can be motivating and inspiring for the audience (Session 2).
- Dialogic space / argumentation: through questioning and dialog the students and/or the audience are allowed to express their views regarding scientific research and explain their choices regarding their own dance moves (Session 1) or discuss the choices of the artists (Session 2).
- Communication of scientific ideas to audience: the workshop allows for the modern scientific ideas or particle physics to be shared with the young audiences (ages 8-13, Session 1), and more mature audiences (ages 16+, Session 2)
- Communities of practice: school community works together during the workshop. After the workshop, schools will be invited to finalise and present the improvised performance, potentially involving parents as audience.

2. Rational of the Activity / Educational Approach

2.1 Challenge

Young students in the current educational environment do not perceive science as a creative or interesting process, but rather as an accumulation of facts to be memorized. In many cases, they are also intimidated by the rigid and the mathematical language and they lose their motivation to understand the real-life implications. This is particularly relevant for girls that have in many cases to face also the absence of appropriate role models. The challenge we are trying to address is to motivate students to engage with scientific topics, by using dance as a means to express particle physics concepts and give them an opportunity to familiarize with those outside the formal classroom setting.

2.2 Added Value

In the school curriculum, particle physics is introduced only in the last two years of school study in the UK (ages 17-18). Through this activity the students are able to learn about particle physics, and even more important to be inspired about science in general. The excitement of young students when they hear about anti-matter is the best witness of this, as well the enthusiastic comments by students and teachers at the end of the workshop.
This workshop also allows the students to experience a genuinely interdisciplinary activity, by employing dance to express scientific concepts. They realize that they can express with dance practically anything, and they are empowered by the opportunity to design their own choreographies, including selecting the music, rather than following a predefined pattern.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the workshop are:

- Understand that matter is made up of elementary particles which are structured into larger particles, for example protons, neutrons and eventually atoms.
- Learn about the 3 families of matter particles.
- Understand that the particles that are responsible for matter and for the forces have different properties. As well as, about the uniqueness of the Higgs boson.
- To learn about anti-matter and its properties.
- To have some idea of how particles interact to create new particles.

3.2 General skills objectives

- Break stereotypes on how scientists look and behave
- Demystify science and scientists

- Bridge the gap between students and the public, in general, and scientists
- Open a channel for dialogue students/public-scientists
- Interdisciplinary: between science and arts
- Communication skills
- To use creative and more familiar skills e.g. dancing, playing games to help access science ideas
- To work with other students who they do not necessarily know, to reach a common target, i.e. team building, which reflects how scientists work today.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

To explain recent developments in science, and in particular the mysterious world of neutrinos, using performing arts and dance. This way science is presented in a more attractive way to students and the audience. The Q&A session aims to create an open channel of discussion student/public-scientist. Students learn by IBSE model to explain science in their own way. Furthermore, the demonstrator aim to satisfy the curiosity of younger students, and show them that asking questions is an important part of science investigation.

4.2 Student needs addressed

- Learn science in a more attractive way
- Satisfy curiosity
- Role model, students see a real scientist
- Possibility to express their worries and questions about science career, scientists and also developments in science.
- Capacity to communicate science
- Game playing and interaction with others (teachers and other students)
- Engaging in fun group activities that has a clear educational purpose
- Freedom of expression to choose their preferred way of dancing

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics (Relevance to national curriculum) Not in the curriculum for these ages. Class information Year Group: 8 (KS3) Age range: 8-13 Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • Trump cards with the names and properties of Standard Model particles • Live music • Teacher guidelines • Where will the learning take place? Dance classroom in school Health and Safety implications? None Technology? As detailed above.

	Teacher support? Yes. Student encouragement as necessary

Prior pupil knowledge: none

Individual session project objectives:
The students by the end of Session 1, should be able to appreciate that the various particles have different properties, and that they can change from one to another either via interactions or through more subtle quantum effects. Furthermore, they will appreciate the many different scales involved, the elementary tiny neutrinos, to the earth, to the sun, to the universe. That things are not what they seem and others are not visible at all: solid masses are constantly penetrated by much smaller ones; our eyes are not the only witnesses of the world; that however far the neutrinos are from the human condition, we can still try to interpret them and to be inspired by them. Their curiosity to explore the mysterious world of particles should be boosted, and through the questions and answer to the physicists should be guided to further exploration.
The audience by the end of Session 2, should be able to appreciate the subtleties of the microcosm, and how particles interact or change from one to another. The subsequent Q&A session here is even more important, not only to support their inquiries/curiosity, but also to correct any possible misconceptions.

Assessment Questioning and dialog through both sessions	Differentiation Students have freedom of choice regarding their expression through dance.	Key Concepts and Terminology Science terminology: Particle physics, neutrinos, quarks, leptons, bosons, matter, antimatter, Higgs boson, photons, mass, Big Bang, the Sun, Oscillations of Neutrinos Arts terminology: dance, performance, improvisation, choreography
Session Objectives: During this scenario, students will deepen their understanding of scientific concepts using their creativity, imagination and freedom of expression.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity

Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Balance and navigation through dialogue aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through dialogue between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through dialogue with different ways of knowledge inspired by interdisciplinarity and personal, embodied learning. Ethics and trusteeship is an important consideration in experimental design and collaborative work, as	Session1: Engage with teacher's questions. Engage in discussion about particle properties.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in particle physics.	*Interact with dance performers*

	well as in the initial choice of question.			

Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from individual, collaborative and communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. Risk, immersion and play is crucial in empowering pupils to generate, question and discuss evidence.	Students propose movements for each particle and discuss the motivation behind their choice	Guides students through highlighting the evidence.	Performing the proposed movements, and putting them together in a choreography.

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using dialogue with each other and the teacher to support their developing understanding.	Students propose choreography of given physics process. Discussing how to express the essential elements, so that the representation is scientifically accurate.	Guides the students, and gives them additional information to excite their interest.	Choreographic representation of particle interactions.

Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider possibilities for explanations that are original to them. They use argumentation and dialogue to decide on the relative merits of the explanations they formulate, playing with ideas.	Students improvise on dance, explaining the reasons for their choices of moves. The choreography is linked to the properties and characteristics of particles.	Workshop leader facilitates and supports as required.	Students use imagination and creativity in expressing particle properties through dance.

Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using different ways of thinking and knowing ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students explore the topic using connections with every day life, for examples cosmic muons are going through our bodies continuously.	Workshop leader facilitates and supports as required.	Creativity in making analogies and connections between dance moves and particle characteristics

Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of possibilities, ideas and justifications through dialogue with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be immersed in a key part of the scientific process. Such communication is crucial to an ethical approach to working scientifically.	Students present the complete choreography, including the sequence of movements representing the individual particles and the representation of the particle interaction. Discussion ensues on their choices.	Workshop leader facilitates and supports as required.	Student dance performance

Phase 7: REFLECT: students reflect on the inquiry process and their learning	Individual, collaborative and community-based reflective activity for change both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	At the end of the workshop, students discuss, probed by workshop leader, about the new acquired knowledge at the end of the workshop as well as to evaluate the process and learning experience.	Workshop leader evaluates through dialogue; then collects and acts on feedback.	Reflection on the process and collection of documentation.

6. Additional Information

The Neutrino Passoire is a dance performance conceived by University of Birmingham particle physicist Kostas Nikolopoulos, alongside with dancers Mairi Pardalaki and Fanny Travaglino, and musician Katerina Fotinaki. The dynamic group of artists, has already performed in prestigious venues, such the Opera of Paris and the Avignon Festival, and with renowned colleagues such as director Romeo Castellucci and singer Angélique Ionatos.

Inspired by the latest 2015 Nobel Prize in Physics, "for the discovery of neutrino oscillations, which shows that neutrinos have mass", the team started working on this elusive and omnipresent particle: The journey from its birthplace, the Sun, to the universe, while oscillating among the three flavours and traversing ordinary matter, like the Earth and our bodies.

These oscillations — where the neutrino forgets and remembers its identity — and the minimal interactions — penetrating matter with no trauma or memory of the event itself— led the artists to reconsider the image of the human body; not as an impregnable and over-sacred fortress as it is often thought of, but as a sort of a colander [(fr.) passoire], open to the outside world. This naturally led to the questioning of the notion of borders, where the team let the neutrinos give the answer.

The Neutrino Passoire was presented in March 2016 as part of the University of Birmingham Arts & Science Festival in a fully-booked auditorium, receiving overwhelmingly positive feedback. A short video teaser of the performance can be found at: https://www.youtube.com/watch?v=QmlNAHwQ4tM

7. Assessment

Short term gained knowledge and understanding is assessed throughout the workshop through questions and discussions with the teacher. Specifically, the choices on the choreography and the music are discussed under the light of the given particle physics topic. Students in general provide complete answers, supported by knowledge acquired during the workshop, suggesting that their understanding has increased.

At the end of the workshop, the students and the teacher sit in a circle, and the teacher invites the students to give examples of things they have learnt and that made an impression on them. Through that the teacher may further assess the knowledge gained and the understanding developed.

The standard CREATIONS evaluation questionnaire is also used in all events.

8. Possible Extension

The students together with their teachers and the support of the scientists and performers involved, could produce a dance performance that could be presented at the school and/or at the national science festivals.

9. References

NACCCE (National Advisory Committee on Creative and Cultural Education) (1999), `All our futures: creativity, culture and education`, London: DfEE.
Ofsted (2003), 'Expecting the unexpected: developing creativity in primary and secondary schools', London: Office For Standards in Education.
Longshaw, S. (2009), 'Creativity in Science Teaching', School Science Review, 90 (332), 91-4.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.73 Fine Arts Workshop

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Ian Andrews, Sarah Fortes Mayer**,** **Konstantinos Nikolopoulos**
Code:	D 3.2.73.	**Contributors:**	
Version & Date:	**V2 28/05/2018**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1. Subject Domain

Particle Physics

1.2. Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (school based).
This is a local activity.

1.3 Duration

1.4 Setting (formal / informal learning)

Informal setting, in a room converted in an art school setting.

Effective Learning Environment

- Informal Learning Environment
- Arts-based: the discovery of the properties of the particles through the study and use of fine art techniques and approaches is a creative approach to learning (Session 1). Developing your own Fine art approach based on session 1 with the potential of working collaboratively in groups. Referencing both increasingly common fine art practice and the necessity collaboration required in particle physics. (Session 2).
- Dialogic space / argumentation: through questioning and dialog the students are allowed to express their views regarding scientific research and explain their choices regarding their own fine art work or discuss the choices of the artists.
- Communication of scientific ideas to other participants through Fine art techniques and approaches: the workshop also allows for the modern scientific ideas of particle physics to be shared with a wider audience through the online platforms and the dissemination of artwork and documentation back at the school community. Indeed the work could form the basis of further developments culminating in an exhibition to which parents are invited.

2. Rational of the Activity / Educational Approach

2.1 Challenge

In the traditional education system, students see science as the learning of a host of given facts that are written. The students do not appreciate that science and research is a continuous process that tries to unveil a better understanding nature. Furthermore, students that are more inclined towards the arts and crafts may not realise the importance of science, nor the similarities between the artistic creative process and research in physical sciences.

2.2 Added Value

Students and young people hear on the news about the recent discoveries in the area of particle physics and this creates curiosity about the subject and a series of questions on the world of particles. This demonstrator addresses the identified need to bridge the gap between the latest scientific breakthroughs and the public of, effectively all ages, in an easy and accessible way. This will satisfy and feed their curiosity at an early stage with the hope it will be sustained in future years.
The topic of particle physics is introduced via the curriculum only at the last two years of school study in the UK (ages 17-18). Younger audiences are equally curious about what matter is made of. Students learn modern concepts of particle physics and how particle physicists work to reveal the hidden structure of nature. This enhances their understanding of

- How science works
- How the particles change from one another, somewhat like changing personalities.
- How particle physicists "see" the seemingly invisible

It also allows them to experience science in a fun and less daunting way. Students have the possibility of interacting with scientists and artists at all times throughout the workshop.

3. Learning Objectives

3.1 Domain specific objectives

The main objectives of the workshop are:

- To learn that matter is made up of elementary particles which form large entities, for example protons and neutrons, and eventually atoms
- To understand that we cannot see the elementary particles, but particle physicists have invented ways of detecting them
- To learn about the Large Hadron Collider (LHC) at CERN as a "motorway" where particles are accelerated to reach very high speeds

- To learn that through such experiments physicists found out 3 families of particles and the corresponding antimatter ones.
- To have some idea of how particles interact to create new particles.
- To understand and appreciate the connections between scientific research and artistic process.
- To develop their ability to express ideas and concepts, using visual art as a language.
- To appreciate the importance of scientific collaboration, and the feedback through constructive discussion.

3.2 General skills objectives

- Break stereotypes (Session 1 & 2) on how scientists look and behave
- Demystify science and scientists (Session 1 & 2)
- Bridge the gap between students and the public, in general, and scientists (Session 1 & 2)
- Open a channel for dialogue students/public-scientists (Session 1 & 2)
- Interdisciplinary: between science and arts (Session 1 & 2)
- Communication skills (Session 1 & 2)
- To use creative approaches and playful experimentation to help access complex Scientific ideas (Session 1)
- To work with other students who they do not necessarily know, to reach a common target (Session 1), i.e. team building, which reflects how scientists work today.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

To explain recent developments in science, and in particular the mysterious world of particle physics using fine art techniques and approaches and exploring the connections between fine art and particle physics. This way science is presented in a more attractive way to students then they can see connections between disparate disciplines. The Q&A session aims to create an open channel of discussion student/public-scientist. Students learn by IBSE model to explain science in their own way. Furthermore,

the demonstrator aims to satisfy the curiosity of younger students, and show them that asking questions is an important part of science investigation.

4.2 Student needs addressed

- Learn science in a more attractive way
- Satisfy curiosity
- Role model, students see a real scientist and fine artists.
- Possibility to express their worries and questions about science career, scientists and also developments in science.
- Capacity to communicate science
- Experimentation, playing and interaction with others (specialists, other students)
- Engaging in fun group activities that has a clear educational purpose
- Freedom of expression to choose their preferred way of creating artistic responses
- Ability to see the connections between disparate disciplines, in this case between fine art and particle physics. Learning to look beyond artificial barriers between subjects.

5. Learning Activities & Effective Learning Environments

Science topic: Particle Physics (Relevance to national curriculum) Particle Physics not in the curriculum for these ages. Class information: Year 11 Age range: 15+ Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need?* • Introductory power point presentation on particle physics • Introductory PowerPoint on visual arts. **Materials** for initial drawings session, activity rota and personal development session. Box of charcoal x 8 boxes Box of pencils 4B x 5 boxes 20 putty erasers Pencil sharpeners x 8

	Felt tip pens fat ones black x 5 packs Masking tape 3 rolls wide A1 paper, 20 sheets Canford 150gm Air drying clay 500gm x 15 Glue guns x5 + black glue sticks x 10 pks Scissors x 5 Pliers for cutting the wire x 5 **Digital projector:** Required for PowerPoint presentations **Lights:** Possibility to eliminate day light for the shadow screen experimentation. Artists will prepare a paper screen on which the shadows will be cast prior to the commencement of the session. **Overhead projector**: Not digital! Portable old-fashioned overhead projector with the lit flat screen and lens for casting shadows and projecting items placed on the screen.

	Extension leads will be necessary to enable safe working of lights and glue guns Where will the learning take place? University or appropriate space at school Health and Safety implications? Glue guns will be hot. Students will need to be mindful. Activity will be supervised. Technology? As detailed above. Teacher support? Yes. Student encouragement as necessary

Prior pupil knowledge: none

Individual session project objectives:
By the end of the first session the students should be able to appreciate that the various particles have different properties, and that they can change from one to another either via interactions or through more subtle quantum effects. Furthermore, they will appreciate the many different scales involved, the elementary tiny neutrinos, to the earth, to the sun, to the universe. That things are not what they seem and others are not visible at all: solid masses are constantly penetrated by much smaller ones; our eyes are not the only witnesses of the world; that however far the particles are from the human condition, we can still try to interpret them and to be inspired by them. Their curiosity to explore the mysterious world of particles should be boosted, and through the questions and answer to the physicists should be guided to further exploration.
During the second session students will be been given the opportunity to develop personal ideas and match them to appropriate artistic techniques necessary for their expression. They will be able to appreciate some of the subtleties of the quantum world, and how particles interact or change from one to another. They will also be able to work collaboratively to develop ideas and approaches as part of a team. The final Q&A session is important, not only to support their personal creativity, but also to ensure evidence-based understand and clear-up possible misconceptions.

Assessment Formal Q&A at the end of each session and discussion ongoing throughout the workshop. Formal critique for the last 30 minutes.	Differentiation In Session 1 (Drawing & Rota of activities) students Will have the opportunity to develop their own ideas within the prescribed experimentation. In Session 2 the students will suggest their own ideas for further development and through tutorials match it to an appropriate method/ technique. There will be an opportunity to work	Key Concepts and Terminology Terminology: Science: Particle physics, neutrinos, quarks, leptons, bosons, matter, antimatter, Higgs boson, photons, mass, Big Bang, the Sun, Oscillations of Neutrinos Fine Art: Fine art practice, Mark making, Tonal development, Quality of line, Visual field, ground, drawing, sculpture, mixed media, Lens–based recording, performance art, collage, assemblage, found objects, figurative/ abstract, site specific.

	collaboratively in small groups at this point.	

Session Objectives: During this scenario, students will deepen their understanding of scientific concepts using their creativity, imagination and freedom of expression.
Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity

Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. Balance and navigation through dialogue aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through dialogue between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through dialogue with different ways of knowledge inspired by interdisciplinarity and personal, embodied learning. Ethics and trusteeship is an important consideration in experimental design and collaborative work, as	Engage with teacher's questions during presentation. Engage with introductory drawing and rota of experimental artistic activities.	Will use challenging questions and the web (images, videos) to attract the students' interest in particle physics.	*Pictures from particle physics experiments and plots from particle physics results with aesthetic value.*

	well as in the initial choice of question.			

Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from individual, collaborative and communal activity such as practical work, or from sources such as data from professional scientific activity or from other contexts. Risk, immersion and play are crucial in empowering pupils to generate, question and discuss evidence.	Students Compare their ideas to existing evidence through discussion.	Guide students to relevant evidence	***Session 1:*** *introductory drawing activity followed by a rota of experimental artistic approches. Introducing the fina art disciplines of drawing (2D), sculpture,(3D) and Lens-based recording.* ***Session 2:*** *Students are able to develop a more personal approach to artwork. Encouraging a mixed media approach and providing the opportunity to work collaboratively.*

Phase 3: ANALYSE: students analyse images and artwork	Students analyse evidence, using dialogue with each other and the teacher to support their developing understanding.	During the critique session students discuss their artistic choices and the connection to the scientific context.	Teacher supports the discussion and further explains the concepts as required.	The critique is both in art and science an important aspect to further our understanding.

Phase 4: EXPLAIN: students formulate an explanation based on evidence.	Students use evidence they have generated and analysed to consider possibilities for explanations that are original to them. They use argumentation and dialogue to decide on the relative merits of the explanations they formulate, playing with ideas.	Students improvise with the various available art forms (drawing, sculpture, shadow screen performance) and explain through that the assigned scientific	Teachers / artists facilitate and support as required.	Students use imagination and creativity in expressing particle properties through various fine art techniques and approaches.

		topic.		

Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using different ways of thinking and knowing ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to interdisciplinary knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students explore the topic using connections with familiar concepts from other disciplines.	Teachers / Artists facilitate and support as required.	Creativity in making analogies and connections between fine art techniques and approaches and particle characteristics.

Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of possibilities, ideas and justifications through dialogue with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be immersed in a key part of the scientific process. Such communication is crucial to an ethical approach to working scientifically.	Students present their artwork, for critique by fellow students and teachers.	Teachers facilitate and supports as required.	Students present artwork in critique to the group and teachers. Students to document work photographically, which provides potential for further artistic expression in itself.

Phase 7: REFLECT: students reflect on the inquiry process and their learning	Individual, collaborative and community-based reflective activity for change both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students discuss their artwork and the new acquired knowledge at the end of the workshop as well as to evaluate the process and learning experience.	Teachers facilitate the evaluative process for students. (conclusions to be written in provided sketchbooks) Evaluates success of workshop through dialogue; then collects	Reflection on the process and collection of documentation. Further study regarding the art methods used.

			feedback sheets.	

6. The Additional information

Fine Arts Workshop with "In–Public" (Ian Andrews/ Sarah Fortes Mayer)

Particle physics/ fine art workshop

Scientific developments have seen reality dissolved into smaller and smaller invisible particles that the physicist has to make visible, a process mirrored by the artist attempting to express thoughts and emotions through the manipulation of materials. Taking the same journey from something hidden to something revealed. Come and experiment with ways of visualising using mark-making, simple three-dimensional materials, photography and film to explore the intriguing connections between art and science.

10.00

Introduction to Physics. 20 mins

Interpretation through art intro. 10 mins

10.30-11.15

First activity 45 mins

Drawing interpretation- creating a charcoal surface/ground and then working into the ground with an eraser, revealing the white paper underneath to create the images. Working from cloud bubble/ chamber images of particle movements. The charcoal ground is disturbed by the movement of the eraser in the same way that the substance in the chambers would be disturbed by the movement of the particles.

11.15-12.15 1hr

Introduction to three further ways to imaginatively visualise and interpret particle movement through a medium-

1. Use of a glue gun on various surfaces to interpret the movement extending beyond drawing to **more experimental approaches in two dimensions.**

2. Use of wire and other materials to create a **three-dimensional interpretation** of the movement in space. Material could include wire and air- drying clay.

3. Use of **shadows on the screen** involving actual movement to be filmed and photographed. Using techniques of a shadow puppet theatre.

Students rotate around these areas. 30 mins each (2 before lunch)

12.15

Lunch break

1.00-1.30

Final rotation around different experimental areas

1.30-1.45 15mins

Briefing on **personal developments/ collaborative activity**

1.45-2.45 1hr

Individual tutorials with students to develop more **personal approaches,** extending and developing the methods used so far (and developing new ones) encouraging mixed media combinations and exploring the possibility of working together in small groups to produce a collaborative outcome.

2.45-3.15 30 mins

Group discussion, critique, evaluation and **feedback.**

7. Assessment

Short term gained knowledge and understanding is assessed throughout the workshop through questions and discussions with the teacher. During the development of the art work, the teacher discusses with the stundents their artistic choices in the context of the topic under discussion. During the critique sessions, the students discuss the work of other students and they give perspectives on what they think the underlying scientific context is, as well as students comment on their work and explain their choices. Students in general provide thoughtful answers, supported by knowledge acquired during the workshop, suggesting the development of understanding on the topic.
At the end of the workshop, the students and the teacher sit in a circle, and the teacher invites the students to give examples of things they have learnt and that made an impression on them. Through that the teacher may further assess the knowledge gained and the understanding developed.
The standard CREATIONS evaluation questionnaire is also used in all events.

8. Possible Extension

The students can continue to develop the artwork produced as the quality and methodology will be appropriate to the National Curriculum for those studying art. The photographs and short videos produced

can be made available on online platforms or can be placed on a memory stick for distribution at the school later.

9. References

NACCCE (National Advisory Committee on Creative and Cultural Education) (1999), `All our futures: creativity, culture and education`, London: DfEE.
Ofsted (2003), 'Expecting the unexpected: developing creativity in primary and secondary schools', London: Office For Standards in Education.
Longshaw, S. (2009), 'Creativity in Science Teaching', School Science Review, 90 (332), 91-4.

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.74 STEAM summer school

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Silvia Verdolini, Edward Duca (University of Malta)
Code:	D 3.2.74.	**Contributors:**	
Version & Date:	V1, 11/5/2016 V2, 9/6/2016	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

STEAM summer school — create the next generation of science communicators in Malta

1.2 Type of Activity

International activity. Training teachers and communicators.

1.3 Duration

- 10-day summer schools for training
- Long term implementation of selected activity

1.4 Setting (formal / informal learning)

The training happens in a formal setting: mix of lectures and practical. The activities shared among participants and activities carried out can be of either form.

1.5 Effective Learning Environment

- Communities of practice (web-based/physical)
- Arts-based
- Experimentation (Science laboratories and eScience applications)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

We would like to bridge the gap between research and education. We bring together and train researchers, and educators. Each category had its own challenge:

- Researchers — they are not necessarily good science communicators, or they do not know how to work in a classroom, or explain things in a simple way.
- Educators — they might not be aware of the latest research, or best ways to bring science into classroom.

STEAM aims at empowering them with various tools available in science communication.

2.2 Added Value

STEAM is a 10-day intensive summer school in science communication. We introduce an innovative form of education that includes Arts into the classical STEM (Science, Technology, Engineering, and Mathematics). Interactive experiments and informal learning with the use of creativity and arts are the key ingredients of our approach. Our ultimate goals are to improve science awareness and develop informed opinions, increase student uptake of STEM careers for high-level jobs, stimulate the socio-economic wellbeing of partner countries, and enhance the transferable skills of current researchers.

The STEAM team has a wide range of science communication expertise that is part of the programme:

- Dialogue and Discourse — theory and practice of science communication
- Managing and Monitoring — how to organise and manage large events and festivals for the public and for schools
- Create and Act —international examples of collaborations between scientists and artists in festivals and theatres
- Media and Journalism —how to write, edit, and create video to effectively communicate science
- Online and Social — how to use online and social media in the most powerful way
- Advocate and Influence — strategies to lobby, work with policy makers, and make your voice heard
- Present and Moderate — how to speak in public and moderate a discussion

3. Learning Objectives

3.1 Domain specific objectives

The main objective of STEAM is to create the next generation of science communicators. STEAM summer school is open to all motivated students and researchers interested in science communication, including teachers, science communication practitioners, science journalists, and established researchers.

This summer school offers participants:

- An introduction to all aspects of science communication with no previous knowledge required
- The possibility to experiment with different ways to engage various public groups with scientific research
- A sneak preview into a science communication career
- An opportunity to improve transferable skills and career development (part of Continuous Professional Development)
- Access to educational materials and already established practices
- Large network for international cooperation and knowledge exchange

3.2 General skills objectives

Skills:

- Learn how to include Arts into the classical STEM (Science, Technology, Engineering, and Mathematics)
- Learn how to use interactive experiments and informal learning with the use of creativity and arts
- Science writing
- Public speaking
- Science journalism
- Theory and practice of science communication
- Social media, blogging
- Science and theater
- Manage and monitor large events for schools

Ultimate goals are:

- to improve science awareness and develop informed opinions
- increase student uptake of STEM careers for high-level jobs
- stimulate the socio-economic wellbeing of Malta
- enhance the transferable skills of current researchers

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the summer school is to train the next generation of science communicators and share best practice in an international setting. We want to empower researchers and educators in the use of formal and informal science teaching with the use of creativity.

4.2 Student needs addressed

Participants to the summer school will be exposed to the latest theory and practice. After a morning of lectures, it will follow an afternoon of practicals where they will be able to work on their own and in groups on specific activities and skills. There will be time to discuss and exchange opinions, share practice and professional experience.

5. Learning Activities & Effective Learning Environments

Science topic: **Science communication, science journalism, social media, management of science festivals,** **Class information** **Year Group: mixed group from different backgrounds. Science undergraduate, young researchers, educators, science practitioners, science journalists** **Age range: above 18 yr** **Sex: both** **Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need? (eg.*printed questionnaires, teleconference, etc.)** **Lecture room with projector, equipment for webstreaming, and space for practical sessions .** **Audiovisual material for social media and online engagement** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **Classroom/lecture hall for the theoretical part of the lecture. Tables and chairs will be moved around when practical sessions are run to allow group work.** ***Health and Safety implications?*** **None** ***Technology?*** **Projector, audiovisual equipment to live stream (Video cameras, Internet, etc.)** ***Teacher support?*** **Each day one topic is dealt with and one lecturer is responsible of both theoretical and practical part.**
Prior pupil knowledge **Basic knowledge of science**	

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***

During this scenario, students will learn different aspects of science communication:

- **Dialogue and Discourse — theory and practice of science communication**
- **Managing and Monitoring — how to organise and manage large events and festivals for the public and for schools**
- **Create and Act — international examples of collaborations between scientists and artists in festivals and theatres**
- **Media and Journalism —how to write, edit, and create video to effectively communicate science**
- **Online and Social — how to use online and social media in the most powerful way**
- **Advocate and Influence — strategies to lobby, work with policy makers, and make your voice heard**
- **Present and Moderate — how to speak in public and moderate a discussion**

Assessment	Differentiation	Key Concepts and Terminology
The practical session will work as a self assessment tool. Participants will be encouraged to put into practice what learned.	*How can the activities be adapted to the needs of individual pupils?* Lecture format and practical can be adapted on specific cases.	**Science terminology: very basic science terminology and knowledge is needed** **Arts terminology: nothing specific**

Session Objectives:

During this scenario, students will learn all aspects of science communication.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Listen and learn science communication theoretical background; Pose questions; Practice personally what learned in the theory; Engage with fellow participants, network and share experience.	Lecturers will use challenging questions, presentations, examples, and the web (images, videos) to keep all participants interested.	Arts are included in the process depending on the activity.
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	During study case sessions students can exchange experience; create an international network of collaborators; learn from their fellows other forms of science communication.	Lecturers acts as facilitators/contributors of the process by connecting people.	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Participants analyse the practical work done. They perform, show, illustrate the work done in the practical session. Analyse difference among work groups,	Lecturers acts as facilitators/contributors of the process.	Lecturers will encourage the inclusion of arts at any stage.

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		and identify strong points and weaknesses		
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Participants explain and re-elaborate what they worked on considering also other outcomes.	Lecturers acts as facilitators/contributors of the process.	
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Participants connect what learned to their own experience, knowledge, and reality. Participants will come up with local strategies for their own reality based on what discussed.	. Lecturers facilitate the connection process by know better the background of each student, and take part of the discussion.	**Use the multi disciplinarity among participants to include Arts in all activities.**
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Share with others possible ideas of collaborations, new features, interconnections, best practice.	Lecturers take part of the discussion.	**Use the multi disciplinarity among participants to include Arts in all activities.**
Phase 7: REFLECT: students reflect on the inquiry	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Discussion and reflections at the end of each practical session and at the end of the summer school will be stimulated.	Lecturers guide/facilitate open, informal discussion	

process and their learning				

6. Additional Information

7. Assessment

Pre- and post- evaluation of the summer school will be conducted. The aim is to test learning gains on the specific topics dealt with. Data regarding gender, profession, seniority, will also be collected.

8. Possible Extension

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.75 Classification Game

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.75.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Biology

1.2 Type of Activity

Local, educational activity based on Creativity- enriched Inquiry Based Approaches (school based).

1.3 Duration

40-60 minutes

1.4 Setting (formal / informal learning)

Formal

1.5 Effective Learning Environment

- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)

2. Rational of the Activity / Educational Approach

2.1 Challenge

Traditional pedagogical techniques often involve immediate delivery of information that is not investigated by the learner but is to be memorised and applied. This acceptance of information from an authority figure without critical examination is suited to a 20th Century culture of routinized work (McWilliam, 2008) but does not suit the requirements of future workers in the advent of the fourth industrial revolution. As advancements in automated technology allow it to expand into both non-cognitive and cognitive routinized work, there will be a shift in the skills needed by human employees. Future skills that will be required include complex problem solving, critical thinking, cognitive flexibility and creativity (WEF, 2016), all of which provide the foundation for robust research. In addition to this, soft skills will also become more relevant as the demand for negotiation, emotional intelligence and effective coordination with others increases. It is therefore important that students are given the opportunity to challenge new information in a dialogic space where they are free to explore new possibilities and employ their creativity. In this way students are able to co-create knowledge, through practice, with open minds and in consensus of their conclusions. These sorts of techniques will become paramount to preparing the workforce of the future and preventing a 'skills gap' (Gordon, 2013).

2.2 Added Value

This demonstrator uses the principles of IBSE to allow students to become co-creators of knowledge as they develop and investigate their own scientific question and analyse the results in coordination with each other. When the initial question is posed, students are encouraged to approach it creatively, developing their own ideas that can be tested and to problem solve their way to their own experimental method. Students will produce their own evidence and are able to consider this critically, discussing their conclusions with others and coming to a consensus through negotiation of how the evidence is to be interpreted. The combination of these activities with artistic exercises will not only give students the opportunity to communicate and embed new scientific concepts into real-world contexts but also to practice their cognitive flexibility as they move between two very different tasks.

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Classification Game' has the following aims:

- Get students interested in nature and how it is classified.
- Allow students to experiment as part of a team.
- Allow students to overcome barriers of motivation and difficulty by creating an engaging activity that uses different approaches to understand the same concept.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

- Apply the principles of science to nature.

3.2 General skills objectives

In the context of the 'Classification Game', students' general skills objectives are:

- Active participation in the negotiation of scientific concepts.
- Develop creative and critical skills.
- Understanding of scientific concepts and phenomena.
- Develop spirit of cooperation and teamwork.
- Articulation of new knowledge.
- Adoption of the principles of science.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative perspective and with practical techniques.

It addresses a key part of the syllabus and can be used by teachers to help students grasp why animals are classified the way they are, particularly if students cannot understand it through normal didactic methods. The discussion at the beginning of the demonstrator will likely divide the class in terms of how animals are classified.

Students can then use scientific experimentation to make conclusions. They are able to see through this experimentation that certain animals have more features in common than others and therefore are classified in the same group. By doing this, students generate new knowledge and draw conclusions as a consensus based on the evidence.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Confusion as to how animals are classified.	*Some animals are difficult to classify (E.g. is a dolphin a fish or a mammal?). This activity provides guidelines that allow students to understand the natural world.*

Ability to draw their own conclusions and articulate them.	*The experiment allows students to discover the solution of their own accord and they can form explanations through experience.*
Ability to understand the importance of the concept and it's relevance to their lives	*The discussion both at the beginning and end of the session will illustrate why classification is important.*
Ability to cooperate, draw a consensus based on evidence and reject theories that have been proven wrong.	*As students perform the experiment themselves they are able to take ownership of the new knowledge and change perspectives while instilling the principles of good science.*

5. Learning Activities & Effective Learning Environments

Science topic: Animal Classification (Relevance to national curriculum) Class information Year Group: Year 4 Age range: 8-9 Years Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Printed hats or vests with a recognisable animal from each group. E.g. Dog (mammal), Eagle (bird), Lizard (Reptile), Frog (Amphibian), Salmon (Fish) and Beetle (Invertebrate).** **Fact sheets for the model animals.** **Fact sheets and charts for the experimental animals.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **In a classroom***.* *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **experiment with theories about which animal belongs to which group and will as a result understand the principles of classification and its importance.**		
Assessment **Assessed as part of the curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** Biological classification, evolution. **Science terminology:** Mammal, Fish, Bird, Reptile, Amphibian, Invertebrate, characteristics. **Arts terminology:** Invention, design
Session Objectives:		

During this scenario, students will **experiment with theories about which animal belongs to which group and will as a result understand the principles of classification and its importance.**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students will guess which animal belongs to which group and there will likely be some division. Students decide who will act as the model animals and who will act as the experimental animals for the investigation.	Will ask students to classify animals. When there is division amongst the class, the teacher will suggest investigating the problem. Some students are appointed as 'model' animals,	

			i.e. animals they are certain belong to that classification group. Others will be the experimental animals.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Using their fact sheets, students move to the correct groups as questions are called out. The experimental animals must chart which of the model animals is in their group after each question.	Teacher shouts out questions (E.g. are you warm or cold-blooded?) and directs the different groups to opposite ends of the room.	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the chart and see which of the model animals was most often in their group.	Teacher asks students to conclude which group their animal belongs to.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain which group they think their animal belongs to based on the outcome of the chart.	Teacher asks students which group their animal belongs to and why. Then makes a chart on the blackboard of the answers.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect the new facts about each animal to facts they already understand about the model animals.	The teacher asks students to explain the controversies. Why did the dolphin have more in common with the dog than the	

			fish? This can be linked to evolution.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students discuss the results and come to a consensus as to which animal belongs where.		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students reflect by choosing a classification group and designing a new animal to fit that group. Students must consider what features it possesses that make it belong to the chosen group.	Teacher asks student to choose a classification group and design an animal that would fit into that group.	Students design a new animal and draw it.

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6. Additional Information

Relevant materials to be found here.

7. Assessment

This can be assessed with pre-evaluation in class, more than two weeks before the activity. A post evaluation can be completed after the event.

The questionnaire can include the SMQII, IMI, 2-EMV and EPoC.

New knowledge can be assessed as part of standard testing.

8. Possible Extension

9. References

Gordon E E (2013) Future Jobs: Solving the Employment and Skills Crisis: Solving the Employment and Skills Crisis. *ABC-CLIO*

McWilliam E (2008) *Unlearning how to teach.* Innovations in education and teaching international 45(3): 263-269

World Economic Forum (2016) The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution. *World Economic Forum* Geneva, Switzerland

D3.2.76 CO2 Play

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.76.	**Contributors:**	James Ciarlo
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Chemistry and Physics.

1.2 Type of Activity

Local educational activity based on Creativity- enriched Inquiry Based Approaches (school based).

1.3 Duration

40-60 minutes.

1.4 Setting (formal / informal learning)

Formal.

1.5 Effective Learning Environment

- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Modern pedagogical trends have shifted towards a constructivist approach, with increased importance being placed on student-centred, self-directed learning (Senocak et al., 2006). A key factor of this is problem based learning (PBL), where students encounter a problem and must play an active role in determining the best solution. In such scenarios the problem may be ill-defined and there is no clear answer or correct approach, however this is thought to mirror the authentic pursuit of science and allow students to develop the skills necessary to tackle scientific inquiry (Greenwald, 2000). In addition to this, there is also more focus being placed on context-based curricula, allowing students to relate concepts learned in the classroom with problems faced in their daily lives to develop a 'need-to-know principle' (Bulte et al., 2006). One challenge then, is linking basic chemistry curricula with these sorts of problems.

2.2 Added Value

This demonstrator uses the principles of IBSE to allow students to approach chemistry from the angle of PBL. Studies have shown that this approach is at the very least, as effective at teaching chemistry as traditional methods and that students develop more positive attitudes towards chemistry and their learning environment (Senocak et al., 2006). In this activity, the properties of CO_2 are found through experimentation and in each case this property is related to a real world application (e.g. use of CO_2 as a fire extinguisher). Student then invent their own gases, with imagined applications tied to the properties of their gas to embed the new concepts of chemical properties and their exploitation. The demonstrator also touches upon the CREATIONS features of ethics and trusteeship as well as risk, immersion, play.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'CO_2 Play' has the following aims:

- Develop an appreciation of the real world applications of chemistry concepts.
- Allow students to experiment as part of a team.
- Allow students to overcome barriers of motivation and difficulty by creating an engaging activity that uses different approaches to understand the same concept.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

3.2 General skills objectives

In the context of the 'CO_2 Play', students' general skills objectives are:

- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop spirit of cooperation and teamwork
- Articulation of new knowledge
- Ability to apply new knowledge to real world problems

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative, hands-on angle.

It addresses a key part of the syllabus and can be used by teachers to help students grasp the the properties of carbon dioxide gas. Students find it difficult to understand the concept of changing chemicals through chemical reactions, particularly when the chemical reactions do not produce a colour change and/or produce a colourless gas. Here, the students are presented with the chemical reaction between vinegar and baking soda. The presence of carbon dioxide as a product is revealed when it is 'poured' onto a burning candle, extinguishing it. The students are then able to use inventive methods to detect CO_2.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*First a question is posed that will likely interest the students. I.e. 'How do you make a fire extinguisher?'*
Ability to visualise the concept.	*The experiments are designed so that students will be able to detect the invisible products of the reaction.*
Ability to draw their own conclusions and articulate them.	*Through experimentation students will establish the properties of carbon dioxide gas.*
Ability to understand the importance of the concept and it's relevance to their lives	*The initial question posed demonstrates the usefulness of understanding gases and their properties.*

5. Learning Activities & Effective Learning Environments

Science topic: Properties of carbon dioxide. (Relevance to national curriculum) Class information Year Group: Form 3 Age range: 13-14 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Small candles, beakers, white vinegar and balloons** **Pen and paper.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **In a science classroom.** *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will **learn how different substances react to form new chemicals and understand how to use scientific methods to detect invisible products.**

Assessment	**Differentiation**	**Key Concepts and Terminology**
Assessed via the normal curriculum.	*How can the activities be adapted to the needs of individual pupils?*	**Science terminology:** Carbon dioxide, gas, pressure, density **Arts terminology:** Design, writing, invention

Session Objectives:

During this scenario, students will **learn how different substances react to form new chemicals and understand how to use scientific methods to detect invisible products.**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students discuss the question of how to detect carbon dioxide gas if we can't see it.	Discusses carbon dioxide fire extinguishers and how they work. Ask students how we can extract an invisible gas. How do we know we've extracted it if we cannot see it?	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students perform an experiment to produce CO2 gas by letting it inflate a balloon.	Teacher guides students through the experiment.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the gas they have produced by comparing it to a balloon filled with their own breath. They should see that the carbon dioxide balloon falls much faster. They then pour the gas onto an open flame to see if it works.	Teacher guides students through the experiment.	

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain why the gas produced by the experiment and exhaled air has different properties.	Teacher prompts students to explain why the balloon containing exhaled air had different properties.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect this knowledge to knowledge of other gases and their properties.	.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students have a discussion about the properties of gases and how this makes them useful for different applications.	Teacher facilitates a discussion about what other properties gases could have.	

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students design a new gas they have discovered. They give it properties and industrial applications and write a story about how this gas and its properties were discovered.	Teacher gives students a task to 'invent' a new gas and describe its industrial application.	The design of a new gas and the story of how it was discovered.

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.

Above: Students experiment with the properties of CO_2.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

CO_2 Play was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore as assessed through standard testing.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator CO_2 Play will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including CO_2 Play, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

Bulte A M W, Westbroek H B, de Jong O & Pilot A (2006) A Research Approach to Designing Chemistry Education using Authentic Practices as Contexts. *International Journal of Science Education* 28(9): 1063-1086

Greenwald N L (2000) Learning from problems. *The Science Teacher* 67(4): 28-32

Senocak E, Taskesenligil Y & Sozbilir M (2007) A Study on Teaching Gases to Prospective Primary Science Teachers through Problem-Based Learning. *Research in Science Education* 37(3): 279–290

D3.2.77 Imploding Can

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.77.	**Contributors:**	William Hicklin
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.2 Subject Domain

Physics

1.3 Type of Activity

This was a local, educational activity based on creativity-enriched inquiry based approaches.

1.4 Duration

40-60 minutes

1.5 Setting (formal / informal learning)

Formal

1.6 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

2. Rational of the Activity / Educational Approach

2.1 Challenge

Scientific concepts can be demonstrated through laboratory experiments, which can provide students an opportunity to play an active role in learning. However, during these practical sessions much of the focus can be placed on mastering techniques and completing the experiment successfully, which detracts from other learning goals. For example, Hodson argues that these sessions should not be there to teach laboratory techniques, more that laboratory techniques should be a means for students to explore concepts in science (Hodson, 1993). Often students are able to understand what happened during an experiment but not why, or can harbour misconceptions that are not evident to the teacher, who may be more concerned with whether or not the experiment was completed successfully (Abrahams & Millar, 2008). Focus on the experimental procedure may also allow little to no time for iteration or reflection, which results in a lack of metacognitive development (Gunstone & Champagne, 1990).

2.2 Added Value

Through the IBSE approach, students first develop their own questions about what has happened. This kind of discussion is able to highlight where students have misunderstood and they can then be guided (Chin, 2004). Focus is placed less on achieving a successful experiment but more on exploring why such a result might be obtained and possible changes in procedure that might affect the outcome. The experiment is then followed by a dance, choreographed by the students, explaining the movement of particles within the reaction. This is an opportunity for collaborative learning, creativity and reflection. The demonstrator also touches upon the CREATIONS features of risk, immersion, play, possibilities and collaborative activities for change.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Imploding Can' has the following aims:

- Re-focus the goals of laboratory experiments on the exploration of scientific phenomena
- Get students interested in science through discussion of possibilities
- Allow students to experiment as part of a team.
- Allow students to overcome barriers of motivation and difficulty by creating an engaging activity that uses different approaches to understand the same concept.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

3.2 General skills objectives

In the context of the 'Imploding Can', students' general skills objectives are:

- Ability to form theories and dismiss those not supported by evidence
- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop a spirit of cooperation and teamwork
- Expression of new knowledge through creative mediums

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative perspective with practical techniques.

It addresses a key part of the syllabus and can be used by teachers to help students grasp how pressure affects molecules, particularly if students cannot understand it through normal didactic methods. Students are first shown the imploding can and are left to question what has happened to cause the can to implode.

The students are then able to re-create the demonstration whilst discussing what is happening inside. Finally students use choreography to represent the molecules in the experiment and show what is happening as the heat and cold is applied.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*By showing the students the demonstration first, the students are able to wonder what has happened and become engaged with the topic.*
Ability to visualise the problem.	*The imploding can shows the effects of pressure in a way that is visible. Students then re-enact the reaction through choreography.*
Ability to apply new knowledge to different problems	*Students must apply their new knowledge to the coordination of a dance.*

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

Science topic: Pressure (Relevance to national curriculum) Class information Year Group: Form 3 Age range: 13-14 year olds Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Bunsen burner set-up, tongs, aluminium can, ice bath.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Science lab and outdoors.** *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will learn **how pressure affects molecules.**		
Assessment **Assessed through the normal curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** **Science terminology:** Pressure, particles, states of matter, implosion, condensation **Arts terminology:** Choreography, coordination, movement, expression
Session Objectives: During this scenario, students will **how pressure affects molecules.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students question what happened inside the and discuss theories.	Demonstrates the imploding can and asks students what happened.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play*	Students repeat the demonstration to		

	is crucial in *empowering* pupils to generate, question and discuss evidence.	investigate what has happened.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the different outcomes of the demonstration and discuss what was required to cause the can to implode.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain what has happened inside the can.	Asks students to describe what happened and why.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect the new knowledge to previous knowledge about molecules and the effect of heat on them.	.	

Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students discuss how the molecules in the can can be portrayed on a larger scale.	Facilitates discussion.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students choreograph a dance to show what happens to the molecules of the can and inside the can during the reaction.	Teacher helps students coordinate and films the dance for students to view.	Choreography of a dance.

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.

Below, students perform and discuss the imploding can experiment.

Above, students perform a dance, representing the particles in the experiment.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

Imploding Can was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore as assessed through standard testing.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator Imploding Can will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including Imploding Can, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

Abrahams I & Millar R (2008) Does Practical Work Really Work? A study of the effectiveness of practical work as a teaching and learning method in school science. *International Journal of Science Education* 30(14): 1945-1969

Chin C & Chia L (2004) Problem-based learning: Using students' questions to drive knowledge construction. *Science Education* 88: 707-727

Gunstone R F & Champagne A B (1990) Promoting conceptual change in the laboratory. In Hegarty-Hazel E (Ed.), *The student laboratory and the science curriculum* London: Routledge 159–182

Hodson D (1993) Re-thinking old ways: Towards a more critical approach to practical work in school science. *Studies in Science Education* 22: 85–142

CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.78 Plastic Ocean

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.78.	**Contributors:**	Alexia Micallef-Gatt
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Chemistry, Biology and Environmental Science

1.2 Type of Activity

This is a local, educational activity based on creativity-enriched inquiry based approaches.

1.3 Duration

2 weeks

1.4 Setting (formal / informal learning)

Formal

1.5 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Complex, internationally relevant issues such as climate change, food security, fossil fuel depletion and so on will shape the scientific debate of the future. It is important that students are able to approach such debates equipped with the skills necessary for good argumentation. As Kuhn (1991) states, argumentation is not a natural skill, but one that needs to be taught and therefore this should be one focus of the classroom. This does not only include use of debate as a learning strategy but it must be facilitated well by the teacher, where listening is encouraged, justification of arguments is prompted and each argument is thoroughly evaluated (Simon et al., 2007).

2.2 Added Value

Dialogue is a major component of this activity, as it is not only a skill that ought to be learnt but can also aid in the learning process. It contributes as a form of collaborative problem-based learning (PBL), where correct solutions are not clear from the outset and students must instead explore the topic through their own questions and that of their peers (Chin, 2004). Teaching through debate therefore not only advances soft skills but also allows deeper contextual and epistemic understanding of the related science topic (Osborne et al., 2004). The use of the de Bono Thinking Hats (de Bono, 1985) in this debate can allow students to explore perspectives different to their own, broaden their comprehension and focus more on cooperative solutions. Aside from dialogue, the demonstrator also touches upon the CREATIONS features of ethics and trusteeship as well as communal activities for change.

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Plastic Ocean' has the following aims:

- Allow students to explore a scientific issue through a wide number of perspectives.
- Get students interested in science within it's real world context.
- Study scientific concepts through the perspectives ethics and the environment.
- Allow students to form opinions about scientific issues and express these opinions in an artistic way.

3.2 General skills objectives

In the context of the 'Plastic Ocean', students' general skills objectives are:

- Develop skills in argumentation including listening and justification of arguments
- Active participation in the negotiation of solutions to scientific issues
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Articulation of new knowledge
- Ability to apply new knowledge to real world problems

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give students the opportunity to learn about a scientific concept in parallel with the social and environmental issues that surround it.

This demonstrator is based on the documentary Plastic Ocean and expands on the points raised in the film. Students can examine this from three different perspectives via three activities related to chemistry, biology and environmental science. The chemistry activity aims to make students aware of the various plastics found in their household, the composition of these plastics and how many of them are recyclable. The biology activity focuses on feeding relationships and how this relates to human health, with students discussing the ramifications of plastic production. The environmental science activity focuses on the effects humans can have on the environment, highlighting how the build up of small actions can lead to bigger consequences.

The students are then able to demonstrate their new knowledge and express their conclusions through artistic follow-up assignments that include dance, drama and the use of un-recyclable plastic to recreate food.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*Screening of the school version of the documentary 'A Plastic Ocean' has emotive narratives that should engage the students.*
Prior knowledge of the issue.	*The documentary will provide a good base of knowledge for the students to expand from.*
Ability to address an issue from multiple perspectives.	*Students will get the chance to see how different sciences can be applied to tackle the same problem.*
Ability to understand the importance of the concept and it's relevance to their lives.	*By using plastics from the students household and allowing them to build their own oceans to pollute, students can connect the issue directly to their own lifestyle and environment.*
Ability to apply new knowledge to real world problems.	*During the arts activity, students are able to express their thoughts on these issues as well as propose solutions.*

5. Learning Activities & Effective Learning Environments

Science topic: Chemistry of plastics, biological feeding relationships, environmental pollution. Class information Year Group: Form 1-3 Age range: 11-14 year olds Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **License for screening the A Plastic Ocean documentary (shortened school version).** **Household plastics, Isopropyl alcohol (45.5%), corn oil, copper wire, corks in test tubes, stirring rod, aceton, Bunsen burner, beakers, tongs, ring stand with guaze.** **Plastic bottle, blue food colouring, floating beads, plastic bag, thick plastic from containers, paper, fruit peels, aluminium foil.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* ***Can take place in an ordinary classroom.*** *Health and Safety implications?* ***None*** *Technology?* ***None*** *Teacher support?* ***Guidance***
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **Know the differences between recyclable and non-recyclable plastics, how to detect them, the relationships between organisms in the marine food chain, the effects of plastic pollution and how to address the issue of plastic pollution from various scientific disciplines.**		
Assessment **Assessed as part of the curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* **Teachers should adapt the difficulty level of discussion and the terms used according to student needs.**	**Key Concepts and Terminology** **Science terminology:** Sustainable, ecology, recycle, micro-plastics, toxic, food-chain, polymer **Arts terminology:** Recycling, emotive art, activism, political art, protest art
Session Objectives: During this scenario, students will **Know the differences between recyclable and non-recyclable plastics, how to detect them, the relationships between organisms in the marine food chain, the effects of plastic pollution and how to address the issue of plastic pollution from various scientific disciplines.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	As students watch the film they are able to pose their own questions about the relevant topics.	Teacher to facilitate a discussion of the points covered by the film.	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students examine the plastics in their home and detect those that are recyclable and those that are non-recyclable. They are also able to create their own ocean and pollute it with plastics to demonstrate the effects of plastic waste.	Guides any students having difficulty.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the issues surrounding plastic pollution from a chemistry perspective, looking into the composition of plastics, from a		

		biological perspective, examining how plastics are sustained through the food chain and affect human health and from an environmental perspective, exploring how plastic waste affects marine ecology.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students can explain how the problem of plastic pollution has grown from a multi-disciplinary perspective.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Students connect the issues related to plastic pollution with pre-existing knowledge of environmental issues	.	

	their evidence and explanations in relation to the original question.	such as climate change and waste management.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate via a debate using the Debono six thinking hats to explore all facets of the debate.	Teacher facilitates the debate and may take on the role of the blue thinking hat.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students must express their ideas, conclusions or feelings about the plastic pollution problem through the medium of art using recycled plastics.		Students can use art to express their stance on the subject of plastic pollution.

6. Additional Information

Above: Students prepare to watch the documentary 'Plastic Ocean'.

Above: Students' artwork with food and marine animals re-imagined from plastic waste.

7. Assessment

Plastic Ocean will be evaluated with a pre-activity questionnaire, taken before the screening of the film. A post-questionnaire will be completed following the students completion of the follow-up assignments.

The questionnaires will include the SMQII, IMI, 2-EMV and EPoC.

Plastic Ocean covers content in the curriculum therefore recall will be tested through normal assessment.

8. Possible Extension

9. References

Chin C & Chia L (2004) Problem-based learning: Using students' questions to drive knowledge construction. *Science Education* 88: 707-727

de Bono E (1985) Six Thinking Hats: An Essential Approach to Business Management. Little, Brown, & Company.

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Simon S, Erduran S & Osborne J (2006) Learning to Teach Argumentation: Research and development in the science classroom. *International Journal of Science Education* 28(2-3): 235-260

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.79 Probability Pyramid

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.79.	**Contributors:**	William Hicklin
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics

1.2 Type of Activity

This was a local, educational activity based on creativity-enriched inquiry based approaches.

1.3 Duration

40-60 minutes

1.4 Setting (formal / informal learning)

Formal

1.5 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

2. Rational of the Activity / Educational Approach

2.1 Challenge

In the standard educational setting, emphasis is often placed on understanding and retention of new knowledge but not on the application of this knowledge to new problems and scenarios. This practice is known as the 'transfer of learning' and can cause issues when students who have memorised concepts are unable to apply them to unique problems raised during an exam (Goldstone & Day, 2012). It is important therefore, that students are trained to transfer knowledge and barriers to this are removed. One barrier is motivation to attempt the problem. As transfer of learning requires effort on the learner's part, they are more likely to expend such effort where there is something to gain (Lobato, 2012). This can be addressed with techniques such as competitive-based learning (CnBL), which has been shown to increase retention and motivation (Cagiltay et al., 2015). CnBL may dismantle barriers to transfer of learning through direct benefits such as winning a game or competition

2.2 Added Value

This demonstrator combines the learning of concepts within probability with a strategy game. Students must apply new knowledge gained about probability to increase their likelihood of winning. With this approach, students are immediately transferring learning to a unique problem but are motivated towards solving this problem as they compete with their peers. This should not only increase retention but train students to transfer concepts they have learned to new scenarios. The demonstrator also touches upon the CREATIONS features of ethics and trusteeship as well as collaborative activities for change.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Probability Pyramid' has the following aims:

- Promote students' ability to transfer learning to new scenarios.
- Allow students to experiment as part of a team.
- Allow students to overcome barriers of motivation and difficulty by engaging students in competition-based learning.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

3.2 General skills objectives

In the context of the 'Probability Pyramid', students' general skills objectives are:

- Skills in the transfer of learning
- Active participation in the negotiation of scientific concepts
- Ability to strategise, applying new knowledge to a game scenario
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop a spirit of cooperation and teamwork
- Articulation of new knowledge

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative perspective using practical techniques.

It addresses a key part of the syllabus and can be used by teachers to help students grasp the probability, particularly if students cannot understand it through normal didactic methods. The discussion at the beginning of the demonstrator raises the question of 'If I roll two dice what outcome is most likely?' which builds curiosity and allows students to develop their own theories.

The students are then able to visualize the outcomes through an experiment involving rolling a dice and putting marbles in a perspex tube that represents the outcome. By doing this, students generate new knowledge themselves by coming to a solution and translating this mathematically. Finally, students play a pyramid game where they must use the concepts of probability as a strategy to win.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*First a question is posed that will likely interest the students. I.e. 'If I roll two dice, what is the most likely result?"*
Ability to visualise the problem.	*The results of the experiment show students a pyramid distribution of outcomes.*
Ability to draw their own conclusions and articulate them.	*Experimentation with the dice and marbles allows students to discover the solution of their own accord.*
Ability to understand the importance of the concept and apply it to new problems	*Students apply the new concept as a strategy to win a game of chance.*

5. Learning Activities & Effective Learning Environments

Science topic: Probability (Relevance to national curriculum) Class information Year Group: Form 3 Age range: 13-14 year olds Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Perspex tubes, marbles, dice.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Outdoors** *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **learn the basic concepts surrounding probability and how they can be applied to predict outcomes of events.**		
Assessment **Assessed as part of the curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?*	**Key Concepts and Terminology** **Science terminology:** Probability, distribution, fraction, outcome **Arts terminology:** Design, strategy, game rules
Session Objectives: During this scenario, students will **learn the basic concepts surrounding probability and how they can be applied to predict outcomes of events.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students are lead to the question of 'which is the most likely outcome when rolling two dice?'	Teacher addresses the subject of games of chance and how they can be beaten.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play*	Students roll dice and call out the results		

	is crucial in *empowering* pupils to generate, question and discuss evidence.	while other students put marbles in the respective tubes.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students bring the Perspex tubes together and analyse the results.	Teacher introduces the distribution shown by the results.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students discuss why some outcomes are more likely than others and why the results have given a distinctive pyramid shape.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students play a new game, where they must design a structure made of different coloured blocks. Each colour is designed to a different	Teacher introduces students to a probability game, where students must design a	

		outcome of the dice. The opposing students must roll the dice and the corresponding coloured block must be removed. Students must therefore connect their new knowledge of probability to the game to place the blocks in strategic positions.	structure and aim that their structure will last the longest.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students discuss with their team what is the most strategic configuration to win the game.		Students design their own structures.
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between	By playing the game, students are embedding the concepts of probability		

REFLECT: students reflect on the inquiry process and their learning	open-ended inquiry learning and the curriculum and assessment requirements of education.	and applying it to a real world problem.		

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.

Above, students bring together Perspex tubes representing the outcome of the dice rolls and see the pyramid that has been formed. Below, students use their probability knowledge to strategise and win a Jenga-based game.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

Probability Pyramid was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore as assessed through standard testing.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator Probability Pyramid will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including Probability Pyramid, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

Cagiltay N E, Ozcelik E & Ozcelik N S (2015) The effect of competition on learning in games. *Computers & Education* 87: 35-41

Goldstone R L & Day S B (2012) Introduction to "New Conceptualizations of Transfer of Learning", *Educational Psychologist* 47: (3) 149-152

Lobato J (2012) The Actor-Oriented Transfer Perspective and Its Contributions to Educational Research and Practice *Educational Psychologist* 47: (3) 232-247

CREATIONS has received funding from the European Commission HORIZON2020 Programme

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.80 Pythagoras' Mountain

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.80.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.2 Subject Domain

Mathematics

1.3 Type of Activity

This was a local, educational activity based on creativity-enriched inquiry based approaches.

1.4 Duration

40-60 minutes

1.5 Setting (formal / informal learning)

Formal

1.6 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

A central focus of modern pedagogy is inquiry-based learning, where students produce their own questions and come to conclusions based on discussion of evidence. It can be difficult to apply this to the field of mathematics, which can often be seen as computational rather than interpretive. Yet, without employing reasoning and argumentation into the teaching of maths, it can be argued that students are not being adequately inducted into mathematical practice (Goos, 2004). This can be seen in particular when students struggle to develop 'algebraic way of thinking', in that they focus too strongly on the answer to algebraic problems and not enough on relations and the representation of a problem (Kieran, 2004). A lack of emphasis on relations and algebraic representation can result in students being able use theorems but not able to appreciate how or why they work. Another issue, is how to engage students in inquiry in the first place. It has been demonstrated that the questions students naturally generate are more often than not inspired by concepts that are personal to them and suggested that this may be an ideal strategy to invoke students' natural curiosity (Chin & Chia, 2004). The question then, is how to relate mathematical problems to concepts that are external to the classroom.

2.2 Added Value

This demonstration ties the Pythagorean theorem to external concepts students are naturally curious about, such as the height of mountains, which allows for inquiry-based method. The focus is then placed on the relationships between the sides of a right-angle triangle which is discovered visually (with legos) by the students. Students are able to translate the relationship they are seeing from English into mathematical language, thereby 'co-creating' new knowledge and developing a sense of ownership over the equation produced. In this way, students are engaged in mathematical practice through argumentation and employ an algebraic approach to the problem. Their discovery is then further embedded in a real-world context, as students draw scenes personal to their own interests them but highlighting right-angle triangles within the environment. This touches upon the CREATIONS feature of interrelationship of different ways of thinking and knowing.

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Pythagoras Mountain' has the following aims:

- Allow students to participate in mathematical practice
- Develop an algebraic way of approaching problems within students
- Get students to associate mathematics within it's real world context.
- Allow students to experiment as part of a team.
- Allow students to overcome barriers of motivation and difficulty by creating an engaging activity that uses different approaches to understand the same concept.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

3.2 General skills objectives

In the context of the 'Pythagoras Mountain', students' general skills objectives are:

- An algebraic approach to mathematical concepts
- Active participation in the negotiation of mathematical relationships
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop a spirit of cooperation and teamwork
- Articulation of new knowledge
- Ability to apply new knowledge to real world problems

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative perspective using practical techniques.

It addresses a key part of the syllabus and can be used by teachers to help students grasp the Pythagorean theorem, particularly if students cannot understand it through normal didactic methods. The discussion at the beginning of the demonstrator raises the question 'How do you measure a mountain?' which builds curiosity and allows students to develop their own theories.

The students are then able to visualize the problem with legos, which can be arranged around a right-angled triangle. Students are able to see through their own experimentation that the number of blocks it takes to create a square around the longest side, is also the same number it takes to create squares around the two shortest sides. By doing this, students generate new knowledge themselves, coming to a solution and translating this mathematically.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*First a question is posed that will likely interest the students. I.e. 'How do you measure the height of a mountain?"*
Ability to visualise the problem.	*Legos are provided that allow the students to see the problem visually.*
Ability to draw their own conclusions and articulate them.	*Experimentation with the legos allows students to discover the solution of their own accord. This solution can then be translated mathematically by the student to produce the Pythagorean theorem.*
Ability to understand the importance of the concept and it's relevance to their lives	*The initial question posed demonstrates the usefulness of the theorem.*
Ability to apply new knowledge to real world problems	*During the arts activity, students are able to explore the wide variety of right-angle triangles that exist in ordinary objects and therefore appreciate how the equation can be applied.*

5. Learning Activities & Effective Learning Environments

Science topic: Pythagorean Theorem Class information Year Group: Form 3 Age range: 13-14 year olds Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Three lego plates to represent the squares around the triangle (e.g. 5cm x 5cm, 4cm x 4cm and 3cm x 3cm).** **Lego blocks to fill the area of the above triangles.** **Pens and paper.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* ***Can take place in an ordinary classroom.*** *Health and Safety implications?* ***None*** *Technology?* ***None*** *Teacher support?* ***Guidance***
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **Prove the Pythagorean Theorem and understand how the equation can be applied to measure objects in the environment.**		
Assessment **Assessed as part of the curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* **Students work in pairs to prove the equation and can assist each other, as well as be guided by the teacher.**	**Key Concepts and Terminology** **Science terminology:** Right-angle triangle, hypotenuse, opposite, adjacent, Pythagoras, theorem, equation **Arts terminology:** Drawing, landscape, scenery
Session Objectives: During this scenario, students will **prove the Pythagorean Theorem and understand how the equation can be applied to measure objects in the environment.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students investigate the question 'how can you measure the height of a mountain?' and pose their ideas for how they think it could be done.	Teacher will introduce the topic of mountains and their heights. If Everest is so difficult to climb how could it be measured?	Students can visually represent their ideas for how to measure the height of a mountain by drawing them.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students work with the legos to see if the area of the large square is really the same as that of the two smaller squares and thereby prove the equation.	Guides any students having difficulty.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students are able to see that the lego blocks of the larger square fit into the two smaller squares.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain whether the equation has been proved or not.	Teacher asks if the equation was proven and why.	

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect the equation back to the original question of how a mountain could be measured using this new information.	.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students communicate how they would now measure a mountain and whether this could be applied to other real world objects.	Teacher asks students how this new knowledge can be applied to the original question and where else it could be applied.	
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	In pairs, students now draw a scene (e.g. beach, park) with right-angle triangles hidden within ordinary	Teacher helps facilitate the game and may give	Drawing of a scene that hides a number of right-angle triangles.

REFLECT: students reflect on the inquiry process and their learning		objects. They then swap drawings and must now find where their partner has hidden his/her right-angle triangles.	students some ideas.	

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.

Above, students wonder how you can measure the height of a mountain, prove the Pythagorean theorem and then draw scenes where right-angle triangles are hidden in everyday objects.

7. Assessment

Pythagoras Mountain was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore was assessed through standard testing.

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator Pythagoras Mountain will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including Pythagoras Mountain, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

Chin C & Chia L (2004) Problem-based learning: Using students' questions to drive knowledge construction. *Science Education* 88: 707-727

Goos M (2004) Learning Mathematics in a Classroom Community of Inquiry. *Journal for Research in Mathematics Education* 35(4): 258-291

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D3.2.81 Snap a Scientist

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.81.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Various

1.2 Type of Activity

This is a national, educational activity which promotes school-research center collaboration.

1.3 Duration

Several weeks.

1.4 Setting (formal / informal learning)

Informal

1.5 Effective Learning Environment

- Communities of practice
- Arts based
- Dialogic Space / argumentation
- Visits to research centers (virtual/physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

The future scientific capacity of any nation depends on a good uptake of talented young minds, therefore one of the most important goals of STEM educators is to encourage students into STEM careers (Schleicher, 2007). However, many barriers still exist between the average student and a career within STEM, such as a lack of awareness or inaccurate perceptions of scientists. Some of these preconceptions include demographical stereotypes – the notion that scientists are white and male, or only come from wealthy backgrounds. There are also preconceptions of a scientist's work environment for example, that work is always performed in a lab.

Research has shown that parents and teachers have a significant effect on career choice (Sahin et al., 2014) and this can be amplified by culture. Malta is a unique case where the entire country has only one main University due to its size and therefore can struggle to accommodate newly trained Maltese researchers who have been trained abroad, resulting in a brain drain phenomena (Sultana, 2006). For this reason, STEM careers can be less encouraged in schools and there is a lack of awareness of career paths. There can also be a lack of connection to university and those who have grown up without exposure to scientists may not have sufficient role models to encourage them towards a STEM career.

2.2 Added Value

Snap a Scientist tackles the stereotypes that surround researchers by exposing young students to actual researchers and their work. Students are tasked with the brief to photograph their researcher in a way that highlights some of the novel things they have learned which were unexpected. The production of a photo series and gallery event can also work to dismantle stereotypes to a broader audience.

Students are able to familiarise themselves with the university and are provided with new role models which may encourage them towards further education, if not further education in STEM. This is important as familiarisation may help to prevent students becoming intimidated by these kinds of career paths. The demonstrator also touches upon the CREATIONS features of possibilities.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The competition 'Snap a Scientist' has the following aims:

- To tackle stereotypes of what a 'scientist' is and what they do.
- To familiarise students with the university.
- To promote different careers within science to young students.
- To provide students with role models within STEM.
- To inspire students to take up a career in STEM.

3.2 General skills objectives

In the context of the 'Snap a Scientist' competition, students' general skills objectives are:

- To develop skills in photography and relate this to scientific subjects
- To understand the work of a researcher
- To be able to communicate complex scientific concepts in an engaging way

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give students the opportunity to explore science and front-line research through an artistic lens. Students who are creatively talented can build on their artistic skills while at the same time exploring STEM fields. Students confident in STEM subjects can grow their creative skills while considering how to communicate science in a creative way.

Students will be introduced to a researcher who will explain their work. This will expose students to real research and real researchers, tackling stereotypes that surround scientific work as well as familiarizing students with STEM career paths. Students will also become familiarized with the university and will take away from this activity a contact and/or mentor to link them to it.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Difficulty understanding front-line research.	*Researchers chosen should be selected based on their ability to explain their work in an accessible way.*
Motivation to understand the work.	*Students selected should be given the option of which researcher they most would like to work with to increase their own agency in the activity.*
Difficulty with photography.	*Students selected to partake in the activity can if necessary take part in a workshop to develop photography skills.*
Difficulty developing a concept.	*Students should be able to form a dialogue with the researcher in order to facilitate the development of a great concept.*

5. Learning Activities & Effective Learning Environments

Science topic: Various (Relevance to national curriculum) Class information Year Group: Any Age range: Any Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Researchers willing to participate.** **Camera equipment if students do not have cameras or smartphones.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **University** *Health and Safety implications?* **None** *Technology?* **Camera equipment if available** *Teacher support?* **Not necessary**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **learn about an area of front-line research, develop an understanding of the roles of a researcher and will communicate this through the means of photography.**		
Assessment **Photographs are assessed as part of the competition.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* A photography workshop can be applied if students do not have creative backgrounds. Researchers should adapt the explanation of their work to the level of the student.	**Key Concepts and Terminology** **Science terminology:** Research, hypothesis, data, publications, **Arts terminology:** Photography, expression, composition, exposure.
Session Objectives: During this scenario, students will **learn about an area of front-line research, develop an understanding of the roles of a researcher and will communicate this through the means of photography.**		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	After selecting a researcher they wish to work with, students will produce their own questions about that researcher's work in order to develop a base for their concept.	Teacher may act as an advisor to help guide student's question.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play*	Students will take on board the information garnered from the researchers as	Teacher may aid student in understanding the researcher's work if the work is complex.	

	is crucial in *empowering* pupils to generate, question and discuss evidence.	evidence for the scientific concept.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students will analyse the scientific concept in order to determine how it could best be communicated.	Teacher may provide ideas and guidance.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students will need to understand the research thoroughly enough to explain it to themselves before they can develop a concept.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	Students can connect the knowledge gained from the researcher with prior knowledge and misconceptions about research and	Teacher can help student connect the resarcher's work to the science	Students use creative skills to develop an artistic concept based on

	their evidence and explanations in relation to the original question.	scientists to develop a concept.	taught in class and can help identify misconceptions the student previously held.	what has been learned from the researcher.
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students use the medium of photography to demonstrate the researcher and their work from a perspective that is contrary to normal preconceptions.		Students take a series of photographs which highlight aspects of the researchers work that was unexpected or interesting.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	A gallery event can be held for students to show off and discuss their work and its meaning.	Teacher provides feedback on student's work.	

6. Additional Information

7. Assessment

The activity can be assessed from two perspectives. Firstly, students work will be assessed as part of the competition from an arts perspective, with suggested indicators being fulfilment of the brief, technical ability, creativity and impact.

The activity can also be assessed for impact on students motivations towards and attitudes to science with pre and post questionnaires. Questionnaires can include the SMQII, IMI, 2-EMV and EPoC.

8. Possible Extension

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

Sahin A, Gulacar O & Stuessy C (2014) High school students' perceptions of the effects of science Olympiad on their STEM career aspirations and 21st century skill development. *Research in Science Education* 45(6): 785–805

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D3.2.82 STEM Escape Rooms

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.82.	**Contributors:**	Hans Joachim Sonntag, Rebecca Jones
Version & Date:	**V1 5.10.2017**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

This activity can be adapted to any subject.

1.2 Type of Activity

This is an educational activity based on inquiry based approaches. It can be performed in school or if performed out of school it can promote school – research center collaboration. It can be both a local or national activity.

1.3 Duration

Should be run for 1-2 hours.

1.4 Setting (formal / informal learning)

This is largely informal learning but the activity can target topics covered by the school syllabus.

1.5 Effective Learning Environment

Learning takes place in a simulated environment where the student takes on the role of a researcher. It is also a dialogic space where students communicate in order to solve problems cooperatively.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

In traditional forms of learning students are passive receivers of information rather than active co-creators of knowledge (Brown, 1994). This makes it difficult for scientific concepts to be understood on a deeper level and remembered long-term. In order to be an active co-creator of knowledge, students need to be engaged, questioning and analysing based on the IBSE model. This is less likely in the standard classroom scenario where students are learning for the sake of learning.

Another issue with traditional methods is that information is given out of context of use and therefore students are often unable to appreciate its relevance to their own needs. It is difficult to memorise information when taken out of context or where there is a long gap between learning of information and its use (Barsalou, 1999).

Finally, due to the imbalanced ratio of teacher to student, it is often not possible for each individual student to receive feedback on a frequent basis and teachers must serve the entire class at once. They must therefore adjust the level of their lectures to suit the needs of students with the least ability, which can frustrate more advanced students (Disessa, 2000). On the other hand, when low ability students find the class too challenging it can affect their confidence and lead them to be even more passive in the learning process.

2.2 Added Value

Games have a unique ability to be able to target the challenges above, all while increasing students' motivation to learn. Educational games can produce a 7-40% increase in learning ability (Mayo, 2009), something which is likely down to the following benefits:

- Motivation – students are motivated to play games through competition and rewards. If learning of new information is required to progress through the game, the potential rewards outweigh the effort of such learning and therefore students can be motivated to grasp even the more challenging concepts.
- Situated Meaning – Games provide information in context of a challenge that needs to be overcome. The new concept has a real use and is therefore more easily remembered.
- Information Dosing – Games release new information as and when it is required. This reduces the gap between learning new information and applying it.
- Individual Learning – Games can cater to multiple students at once on an individual basis. This means that feedback can be given instantly and the level of learning can be adapted to the ability of the student.
- Cooperation – Games can allow for students to cooperate towards a common goal, creating a dialogic space where students can contribute based on their own skills.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The STEM Escape Rooms domain specific objectives are to:

- Get students interested in science and research through a semi-simulated environment
- Give students an understanding of what it means to be a researcher through role-play
- Teach students advanced STEM topics and allow them to overcome barriers through problem solving within a game scenario
- Give students an appreciation of the importance of science within context and the importance of decisions that surround science
- Build student's confidence in their ability to understand science
- Familiarize students with the university and motivate them into STEM careers

3.2 General skills objectives

In the context of STEM Escape Rooms, students' general skills objectives are:

- Skills in cooperation and collaboration with other players
- Understanding of new scientific concepts
- Development of skills in critical thinking and analysis
- Connect research and its implications with wider society

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to offer students the opportunity to learn within an authentic context, where new information is not delivered for the sake of learning but is needed by the student to fulfill their own objectives. Scientific concepts within the game are not delivered all together but are available incrementally, as they are required to solve a problem and therefore they are used immediately as they are learnt. This allows students not only to form their own inquiries but to learn through practice and become 'co-creators' of new knowledge.

Within a game scenario, the desire to contribute to the team, compete and earn rewards can increase motivation to learn, allowing students to tackle difficult concepts which may require a more sustained effort. Overcoming these difficult puzzles can increase students' confidence and willingness to attempt challenging problems in future, as well as increase students' estimation of their own ability in science.

Through role-play, the students can experience a researcher's role first hand and appreciate the way research is performed and the importance of decisions taken around new knowledge and technology. Playing the role of a researcher can break down barriers between how students view themselves and what they envisage they can become, as it allows students to familiarize themselves with the university. This may open up possibilities of a career within science.

4.2 Student needs addressed

We have identified the following needs of students participating in the activity and the solutions to address them:

Difficulty starting the puzzles.	*Live actors took part in the game to guide students through the challenges. Students were also allowed to play in teams.*
Advanced STEM topics covered (i.e. western blots).	*Puzzles were designed so that only the basics needed to be understood to solve them and much of the background science was avoided.*
Motivation to play the game.	*Competitive elements were added such as making the game time-dependent and rewarding students with extra points for completing bonus puzzles and making correct decisions.*
Navigation through the university which may be unfamiliar to students.	*Live actors also took the role of escorts, taking students between the rooms while remaining in character to sustain the immersive experience.*

5. Learning Activities & Effective Learning Environments

Science topic: Various. Class information Year Group: Open to 14-18 year olds. Age range: 14-18 Sex: Both Pupil Ability: The scenario allows for students of varying abilities.	Materials and Resources Several rooms are needed to suit each scenario. E.g. a lab is needed for the biology puzzle. Props both to dress rooms and provide materials necessary for the puzzle. E.g. biology puzzle requires a number of unlabeled western blots in a folder. Actors are required to act as escorts and guides, ensuring the game is played safely, that students can complete the challenges and that nothing is damaged.
Prior pupil knowledge: Unknown	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will follow their own initiative, seeking out knowledge to solve puzzles, thinking critically about new information presented and apply new knowledge to the scenario to progress. After the session, they should have learned several new scientific concepts dependent on the narrative of the game.	

Assessment	**Differentiation**	**Key Concepts and Terminology**
The game can be preceded and followed by knowledge tests.	*How can the activities be adapted to the needs of individual pupils?* Game difficulty can be adjusted according to age group. Within the game actors can increase guidance levels according to student ability.	**Science terminology:** Evidence, analysis, critical thinking, problem-solving **Arts terminology:** Role-play, drama, simulation

Session Objectives:

During this scenario, students will students will follow their own initiative, seeking out knowledge to solve puzzles, thinking critically about new information presented and apply new knowledge to the scenario to progress. After the session, they should have learned several new scientific concepts dependent on the narrative of the game.

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	During the course of the game, students will develop their own questions which they will need to answer in order to progress.	May prompt students as to where to begin their investigation.	Role-play as a researcher in a crisis scenario. Students follow the narrative of the actors and identify the question.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will gather evidence from documents available in the room.	May prompt students to examine certain objects.	Students examine the objects in the room: diaries, notes, manuals and build a picture of previous events of the story.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students must analyse clues left in the room to come to conclusions.	Teacher may aid in discussing the implications of the clues.	Students apply the clues to the narrative to come to conclusions.
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students can use the evidence and conclusions drawn to explain the sequence of events in the narrative.	Teachers must take the explanations given and based on these explanations escort students through the narrative.	Students build theories of what had occurred in the room and apply this to the progression of the story.

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students can connect their background knowledge of science to the puzzles at hand to aid investigation.	.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students must discuss with each other how to proceed through the game, what conclusions should be drawn and what key decisions will be made to affect the outcome of the story.		In the simulated environment students must imagine they are making critical decisions that will affect the lives of others.
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students will view a personalized ending film which will allow them to reflect on the decisions made about their discoveries and how this has affected their story.		

6. Additional Information

Escape rooms are rooms in which a player is locked until they solve the puzzles and 'escape'. The Escape Malta game comprised of 6 consecutive puzzle rooms which followed a narrative. Players took on the role of a researcher at the University of Malta during a pandemic and had to navigate the university, solving problems to progress and eventually escape the university and survive. An actor greeted players at the start of the game, introducing themselves as a colleague who would now be working with them. The actor took on the role of an escort to ensure players navigated the course correctly, were safe and also were given guidance if they were struggling to initiate a puzzle.

Each puzzle room addressed a different STEM field. For example, in the first room which was related to biology, players had to investigate the source of the pandemic by analysing western blots. Once this information had been found they needed to communicate it, however they discovered the internet was down. The actor would then take them to the next room where a puzzle based on IT required them to restore the internet.

Throughout the game players would also need to make key decisions which affected the outcome of their story but also would award them bonus points if the correct decision was made. These decisions were based on RRI keys. For example, when the players had restored the internet they had to decide whether to release information about the pandemic publically or to only communicate it to the authorities. This decision touched on open access.

Once players finished the course, their points were calculated and based on the score they either 'survived' or 'almost survived'. Players could also watch a personalised ending video which was based on the decisions they had made throughout the game.

Above shows two groups of players who 'survived' the game.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

7. Assessment

Questionnaires were given to students a few weeks before the activity and then again straight after the activity. For pre-evaluation, online forms were created to sign students up for the activity which allowed them to choose a date and time to play. This online form also included sections pertaining to evaluation. For post-evaluation, after the activity the same questionnaire was given as a paper version while staff were calculating the student's scores for the game.

The questionnaire included the SMQII and IMI. It also included the 2-MEV, as the game raises issues relating to the effect of science on the environment in the form of the leak of a hazardous industrial chemical into the open sea. Therefore, we were interested if the game increased the student's concern in this area. The post-questionnaire included a cognitive load section which asked about each puzzle room as well as the game overall.

8. Possible Extension

The current implementation was a pilot, however due to its success University of Malta is planning to run the game at two further points during the year. We will run a series of events during the Easter break and a second series of events during summer at a national level.

9. References

Barsalou L W (1999) Language comprehension: Archival memory or preparation for situated action. *Discourse Process* 28: 61-80

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Disessa A A (2000) Changing Minds. *MIT Press* Cambridge, MA

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CREATIONS has received funding from the European Commission HORIZON2020 Programme

D3.2.83 The Ozone Game

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.83.	**Contributors:**	Edward Duca
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Chemistry

1.2 Type of Activity

This was a local, educational activity based on creativity-enriched inquiry based approaches.

1.3 Duration

40-60 minutes

1.4 Setting (formal / informal learning)

Formal

1.5 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

2. Rational of the Activity / Educational Approach

2.1 Challenge

Games / simulations are an emerging technique for teaching science as they provide a contextual basis for learning, are inquiry-based and improve self-efficacy (Barab & Dede, 2007). Particularly when such simulations are adequately prepared by the teacher, students can benefit greatly from the activity (Chen & Howard, 2010). Yet one drawback of these techniques is that many of these games ignore the physical experience. Physical interaction with scientific phenomena can enhance understanding and memory through embodied cognition (Kontra, 2015). This occurs when sensorimotor brain systems are activated in association with relevant concepts, even when physical stimulus is no longer present. This kind of embodied learning puts the student at the centre of the scientific phenomena rather than outside of it as an observer and can result in richer, more contextual knowledge.

2.2 Added Value

In addition to the CREATIONS aim of a student-centred approach, this demonstrator combines both the benefits of game-based learning and / or simulations with embodied learning. The activity is first preceded with an introduction to chemical reactions in the atmosphere to prepare students. Students then become the particles within a reaction and through playing a game, effectively simulate the process of a chemical reaction between oxygen, photons of light and chlorofluorocarbons. The outcomes of these games provides a foundation for understanding the outcomes of the reactions from a first-person perspective and sensorimotor association may aid memory. The use of the interactive game as a platform for learning enhances motivation and autonomy of students, consequently increasing their engagement with the subject matter. Students demonstrate their new knowledge through the development of a short play. This touches upon the CREATIONS features of ethics and trusteeship, dialogue, risk, immersion, play and collaborative activities for change.

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'The Ozone Game' has the following aims:

- Employ embodied learning for increased understanding of complicated reactions
- Increase students motivation and self-efficacy towards science through game-based learning
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.
- Allow students to visualize scientific concepts that are not readily visible.

3.2 General skills objectives

In the context of 'The Ozone Game', students' general skills objectives are:

- Articulation of new knowledge through personal experience
- Active participation in the negotiation of scientific concepts
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop a spirit of cooperation and teamwork
- Ability to apply new knowledge to real world problems

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative, hands-on angle.

It addresses a key part of the syllabus and can be used by teachers to help students grasp the process of a reaction by allowing them to visualize the components in a way that is difficult to achieve through traditional methods. The discussion at the beginning of the demonstrator raises the question of 'Why do we have an ozone layer?' which builds curiosity and allows students to develop their own theories.

The students are then able to visualize the reactions that take place in the atmosphere by becoming part of the reaction. They take on the role of atoms, molecules and particles in the reaction and play a game, of which the rules are decided by chemistry. Students are then able to demonstrate for themselves the outcome of the reaction, making the concepts easier to grasp. Students are also encouraged to think about the consequences of the damage to the ozone layer and communicate the series of events that lead to the break down and repair of the ozone layer through the medium of a play.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*First a question is posed that will likely interest the students. I.e. 'Why do we have an ozone layer?"*
Ability to visualise the concept.	*Students become the elements within the reaction and therefore demonstrate and experience first hand the outcome.*
Ability to draw their own conclusions and articulate them.	*Experimentation during the game allows students to discover the solution of their own accord. The outcome of the game can then be explained and linked to chemistry.*
Ability to understand the importance of the concept and it's relevance to their lives	*Students are encouraged to discuss the effects of CFC's on the ozone layer and the consequences of that damage. They then produce a play surrounding these themes.*

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5. Learning Activities & Effective Learning Environments

Science topic: The ozone layer. (Relevance to national curriculum) Class information Year Group: Form 3 Age range: 13-14 year olds Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Bibs of three different colours** **Material for costumes** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Outdoors** *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

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Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will **learn about the composition of the atmosphere, how naturally occurring reactions lead to a build up of ozone, the damage caused by CFCs and the consequences of that damage.**		
Assessment **Assessed as part of the curriculum.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* **Students can choose the roles they will play in the reaction as some require more movement than others.**	**Key Concepts and Terminology** **Science terminology:** Photon, ozone, molecules, chlorofluorocarbon, atmosphere, aerosols **Arts terminology:** Script, stage, choreography, narration, characters
Session Objectives:		

During this scenario, students will **learn about the composition of the atmosphere, how naturally occurring reactions lead to a build up of ozone, the damage caused by CFCs and the consequences of that damage.**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Based on the knowledge of how ozone forms, students must guess what will happen if oxygen is left exposed to UV light uninhibited. E.g. will ozone build up or will there be a mixture of ozone and oxygen molecules.	Deliver background knowledge of how ozone forms and pose the experimental question.	

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students play a game where they become elements of the reaction bound by the rules of chemistry. Oxygen atoms must form pairs or threes. Photons of light must travel in straight lines, breaking apart oxygen molecules but not ozone. The game can be repeated, however one student takes the role of a CFC and is able to break ozone apart.	Explains the rules of the game and ensures the game is played fairly.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	At the end of each game, students can look at the		

		composition they are in and analyse the results of the game.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students can explain why ozone accumulated in the first game but not in the second.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students connect this back to chemistry and discuss what is the outcome of the chemical reactions.	.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students discuss the effects of CFCs on the atmosphere and the consequences of this.		

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students perform a play to demonstrate the story of the ozone layer with molecules, atoms and particles as characters in the story.		Students perform a play to communicate the events that occurred surrounding the ozone layer.

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.

Below, students dressed in yellow represent the oxygen atoms and students in orange represent the photons of light in the Ozone Game.

Above, two 'oxygen atoms' form an O_2 molecule.

7. Assessment

The Ozone Game was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore as assessed through standard testing.

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator The Ozone Game will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including The Ozone Game, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

Barab S & Dede C (2007) Games and Immersive Participatory Simulations for Science Education: An Emerging Type of Curricula. *Journal of Science Education and Technology* 16: 1-3

Ching-Huei C & Howard, B (2010) Effect of Live Simulation on Middle School Students' Attitudes and Learning toward Science. *Journal of Educational Technology & Society* 13(1): 133-139

Kontra C, Lyons D J, Fischer S M & Beilock S L (2015) Physical Experience Enhances Science Learning. *Psychological Science* 26(6): 737-749

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.84 Visible DNA

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Amanda Mathieson
Code:	D 3.2.84.	**Contributors:**	Edward Duca
Version & Date:		**Approved by:NKUA**	

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Biology

1.2 Type of Activity

Local, educational activity based on Creativity- enriched Inquiry Based Approaches (school based).

1.3 Duration

40-60 minutes

1.4 Setting (formal / informal learning)

Formal

1.5 Effective Learning Environment

- Dialogic Space / argumentation
- Experimentation (Science laboratories and eScience applications)
- Arts-based

2. Rational of the Activity / Educational Approach

2.1 Challenge

The laboratory experiment, while a solid element of the school science curriculum, is found to be lacking when it comes to modern teaching goals. For one, the process is often not inquiry-based and there is an emphasis on completing the experiment successfully rather than understanding the scientific concept as well as the experimental design and process (Gunstone & Champagne, 1990). Commonly there is little time left for discussion of new ideas or application of them. This means no opportunity for retrieval-based learning (RBL), where concepts can be further embedded by being retrieved for different tasks (Karpicke). As Lunetta describes '*To many students a 'lab' means manipulating equipment but not manipulation of ideas*.' This is despite the fact that cooperation and discussion leads to increased confidence and ability amongst students (Lunetta, 1998). It has been shown that a self-regulated approach to learning in the lab can be successful and positive experience for students, particularly when followed by cooperative assessment (Witteck et al., 2007).

2.2 Added Value

This demonstrator takes an inquiry-based approach to a traditional laboratory experiment for extracting DNA, where discussion of the methods for extracting DNA is encouraged. Protocol techniques are linked to everyday objects (e.g. dish soap and its ability to break down the lipid bilayer) as well as social issues such as racism. Emphasis is not placed on students completing the experiment successfully but on the planning of the experiment and the methods used, which is self-regulated by the students. This is followed by a role-play game, where the new concepts must be used to compete cooperatively in teams, which not only offers an opportunity for students to collaborate but also for RBL, further embedding the new knowledge gained from the experiment. Through this game, the demonstrator touches upon the CREATIONS features of ethics and trusteeship as well as risk, immersion, play and empowerment and agency.

3. Learning Objectives

3.1 Domain specific objectives

The demonstration 'Visible DNA' has the following objectives:

- Switch from traditional experimental goals to a collaborative learning environment
- Get students interested in science within its real world context.
- Allow students to compete in an RBL exercise as part of a team.
- Allow students to overcome barriers of motivation and difficulty by creating an engaging activity that uses different approaches to understand the same concept.
- Provide teachers with an easy to implement demonstration which approaches a difficult topic creatively.

3.2 General skills objectives

In the context of the 'Visible DNA', students' general skills objectives are:

- Design, planning and discussion of research methods
- Active participation in the negotiation of experimental outcomes
- Develop creative and critical skills
- Understanding of scientific concepts and phenomena
- Develop spirit of cooperation and teamwork
- Articulation of new knowledge
- Ability to apply new knowledge to real world problems

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to give the opportunity to understand a scientific concept which students normally struggle with by approaching it from a creative, hands-on angle.

It addresses a key part of the syllabus and can be used by teachers to help students grasp the concept of DNA being a key component of most living organisms. It can be difficult to appreciate this through didactic methods as DNA is not visible to the naked eye. The discussion at the beginning of the demonstrator raises the question of what DNA looks like and whether we can find it in fruit, which builds curiosity and allows students to develop their own theories.

Students are taken through the procedure of DNA extraction and are able to see DNA they've extracted from bananas. They are then asked to visualize the molecular structure of DNA and are introduced to the A-T, G-C pairing. This should allow students to begin to appreciate that the body is full of tiny molecules that together make up an organism.

4.2 Student needs addressed

The following needs of the students were identified as well as methods to cater to those needs:

Motivation to address the problem.	*First a question is posed that will likely interest the students. I.e. 'What does extracted DNA look like?'*
Ability to visualise the concept.	*Students are able to extract DNA and see it, thereby connecting them to the concept of DNA in living organisms.*
Ability to understand the importance of the concept and it's relevance to their lives	*Students are guided to the conclusion that DNA is in almost all living organisms including themselves.*

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

Science topic: DNA (Relevance to national curriculum) Class information Year Group: Form 3 Age range: 13-14 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Fruit: 6 bananas** **Ice & container to cool alcohol** **Toothpicks or small kebab sticks: 50 individual sticks** **Small filters, handheld: 21 filters (see image)** **Plastic cups: 300** **Soap detergent: 1L** **Table salt: 500g or more** **70% or higher isopropyl alcohol: 3L** **Test tubes or clear containers: 40 (not too small)** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Science lab** *Health and Safety implications?* **None** *Technology?* **None** *Teacher support?* **Guidance**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will **learn that while DNA is mostly invisible exists in almost all living organisms.**

Assessment	**Differentiation**	**Key Concepts and Terminology**
Assessed as part of the curriculum.	*How can the activities be adapted to the needs of individual pupils?*	**Science terminology:** DNA, dissolve, detergent, phospholipids, alcohol, precipitate, pipette, DNA sequence **Arts terminology:** Role-play, code, decipher

Session Objectives:

During this scenario, students will **learn that while DNA is mostly invisible exists in almost all living organisms.**

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students are lead to the question of what DNA looks like and establish their own theories.	Teacher encourages students to guess what DNA looks like.	
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play*		The teacher should discuss the reasoning behind each stage of the protocol. E.g.	

	is crucial in *empowering* pupils to generate, question and discuss evidence.	Students extract DNA from bananas so it is visible in a test tube.	the detergent is necessary to break down lipid membranes.	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the DNA and make a note of amount and appearance.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students explain why the DNA was present in the banana and how they were able to extract it.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Students must connect their explanation to existing knowledge, for example what a detergent is and what it does. What cell	.	

		membranes are made of.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Through a discussion, students conclude what the molecular structure of DNA looks like and what pairs the nucleotides make.		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students write each other a message using DNA code. Each A, T, C or G in the message must be swapped for its complementary letter. They should then swap letters, 'extract' the code and translate it. This should embed the DNA code and pairings in the students.		Role play as a spy writing secretive notes using DNA code.

6. Additional Information

This demonstrator was created through STEAM School Malta, an initiative where researchers as well as undergraduate and postgraduate students of science are trained in the CREATIONS pedagogical framework, create a demonstrator with guidance from CREATIONS and then deliver those demonstrations at schools.


Above, students are able to extract DNA.

Below, a student hides a DNA sequence in their message to another team.

7. Assessment

Visible DNA was implemented in two schools, catering to approx. 300 students. In both cases, students completed a pre-evaluation, in class, more than two weeks before the event. A post evaluation was then completed after the event in paper format.

The questionnaires included the SMQII, IMI, 2-EMV and EPoC.

Content of the demonstrator was related to the school curriculum and therefore as assessed through standard testing.

8. Possible Extension

The training of researchers as well as undergraduate and postgraduate students of science in the CREATIONS pedagogical framework will expand the impact of the project by producing CREATIONS ambassadors, who will carry this framework into their science communication activities.

The demonstrator Visible DNA will be delivered in schools through four further STEAM School Malta events. Each event will be hosted within a school where classes will rotate around several demonstrators, including Visible DNA, for an entire afternoon or morning. Each event will cater to approx. 150 students.

9. References

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D3.2.85 May Month of Mathematics (M3)

Project Reference:	H2020-SEAC-2014-1 , 665917	**Authors:**	**Dobrivoje Lale Eric and Djurdja Timotijevic (CPN)**
Code:	D 3.2.85.	**Contributors:**	
Version & Date:	v1.0, 27th May 2016	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics

1.2 Type of Activity

Science Center based – Large scale National Activity

1.3 Duration

- two months (maximum time with preparations for organization of whole one-month event)
- two hours (a minimum time for individual or group visit for pupils / children)

1.4 Setting (formal / informal learning)

Informal, but the meetings during the preparation phase could be as well in schools, teachers' associations, science centers / museums...

1.5 Effective Learning Environment

- Communities of practice
- Arts-based
- Dialogic space / Argumentation
- Communication of scientific ideas to audience

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Mathematics in Serbia, but probably all over Europe, is perceived by general public as inadequately taught to the pupils in 21st century and, subsequently, distant, hard to understand and reserved for small group of gifted ones. According to the research results from 2012 in Serbia (CPN 2012, conducted MASMI Public Opinion Research Agency), among all STEM subjects, mathematics controversially stands out as the most loved and the most hated one. More than 50% of respondents stated that math is/was the subject they hated the most, nevertheless, for 25% of respondents math is/was the most favourite one. Those results were not a surprise for researchers. The traditional methods used for teaching mathematics in schools really do present mathematics as an abstract, distant, complicated discipline, with no relation to everyday life and personal experience of students. Ii t is also presented as a discipline that is not for everyone, but for those most intelligent and talented ones. In line with that, special attention is put on additional math education for gifted students (Mathematical gymnasium, Science Center Petnica, Mathematical Institute of Serbian Academy of Sciences and Arts, etc.) while formal mathematics teaching in everyday classroom in primary and secondary school stays outdated, unimaginative, curricula demanding and too formal.

2.2 Added Value

For applying contemporary practices and recent interactive math programs in Serbia, Center for the Promotion of Science, together with Mathematical Institute of Serbian Academy of Sciences and Arts and many other local, national and international partners, established in 2012 May Month of Mathematics (M^3) programme as a mean to present mathematics from different perspective and with different values – creativity, applicability and connection to everyday life.

The main idea of the program is that math is beautiful, creative and fun, and the goal is to show that side of math to the audience, who is usually stuck in their stereotypes of mathematics as a scary school subject. The main idea behind all the planning and the execution of the M^3 program is to make it obvious to as broad general public as possible just how fascinating math is, how imaginative and inspiring for artists as well as scientists it can be, if it is presented in a different manner than usually is. The team behind the organization of M^3 program uses all means available to uncover that side of mathematics, to people of all ages and interests. For example:

– we use mathematical cartoons to attract even very young children,

– building simple geometrical objects out of everyday items is a great tool of sparking the curiosity of the youngest children,

- short documentary movies on fascinating math phenomena are constantly being screened, to quickly and effectively attract casual visitors who are not necessarily motivated to learn about math,

– interactive exhibits are made in a way that gets the audience quickly involved, inviting them to solve a puzzle or presenting them with something unexpected, getting them motivated to find out the mathematical explanation behind it,

– for school kids workshops are organized, where the topics they're learning about in their schools are presented in a completely new, interactive and inclusive way,

– the advanced audience gets a chance to meet world famous mathematicians and to listen to their lectures while debated with them in an open atmosphere.

We believe that M^3 concept is a good example of RRI practices for several reasons:

- M^3 is tackling science education in a specific way, targeting not just pupils in the classroom, but young people out of the school, their parents and teachers, and everyone interested, as an fantastic example of **public engagement,**

- Since it is making math more available, more understandable, more applicable and more fun, it consequently attracts more students to science what should eventually result in:

    - increased science literacy among general public, making them able to be involved in a dialogue with science and research community,
    - more students interested in a science career.

3. Learning Objectives

3.1 Domain specific objectives

- promotion of mathematics as fundamental science, used in all other sciences, humanities and creative disciplines
- promotion of programs of math faculties and Mathematical Institute
- stimulation of mathematical activities as part of informal learning – math societies and clubs
- presentation of similar programs and achievements from different European countries (Germany, France, Italy, Austria, Holland…)
- Serbian edition of famous math books by contemporary authors, such are Gunter Ziegler, Cedric Villani and Keith Devlin
- promotion of the mathematical projects and programs funded by the European Commision

3.2 General skills objectives

- active participation in the negotiation of scientific concepts
- development of creative and critical skills
- understanding of mathematical concepts and phenomena, and their presence in everyday life
- interconnection of math with various aspects of arts
- development of cooperation and teamwork
- students will learn to realize common impulses between discipline knowledge in
- both science and arts
- pupils will learn to make their own decisions during inquiry processes and
- reflect on outcomes

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

General concept and the ideas of May Month of Mathematics are recognized and supported by different educational instances throughout Serbia. Direct cooperation is established with Ministry of Education, Science and Technological Development, Serbian Academy of Sciences and Arts, regional and local educational authorities, scientific institutes, universities and faculties, primary and secondary schools, and informal learning professionals. Such a large programme needs a support on every possible level, and for its success it is crucial to be exceptionally well connected and open for different options and adjustments.

As so far five completely different programs were organized (2012–2016), each of them have had a unique visual identity and a topic that is serving as an umbrella for diverse content. Those uniting topics are always inserted very general, but also inspiring and attractive like "Math and Nature", "Math and Arts", "The Rhythm of Mathematics" etc. Belonging elements of each program are describing symbolic and practical meaning of the overarching theme. However, in addition to its content, visual identity is constructing a strong appearance which is influencing audience in a way that they should connect and analyze different activities under the same M^3 program.

Primary target group is always high school children as they're approaching the phase when they have to decide what kind of faculties, and subsequently, what kind of careers they will choose. Next target group is primary school children with goal to engage them more with science introducing the concept of scientific culture and interdisciplinary approach. Finally, M^3 programs are always influencing general audience, both those directly involved and those that are maybe just passing by our venues. In that sense, it is necessary to provide those venues where people are usually coming or at least passing by – not only those which are recognized as parts of formal or informal learning setting. Furthermore, M^3 is always asking for and using the support of the university students that are standing as volunteers or educators in the process. However, they're acting the important role as mediators between pupils and scientific content.

May Month of Mathematics therefore needs active participation of at least several professional groups:

- Math and science teachers, pedagogues,

- Scientists (mathematicians, but also others from represented disciplines as well),

- Informal educators and trainers,

- Students of math faculties (also from other scientific faculties, represented disciplines and faculties for professional education and arts).

4.2 Student needs addressed

Children, teachers and general audience are placed in M^3 setting which is encouraging and supporting their active participation, personal and group investigation, and critical thinking and questioning. However, as the final outcome, several M^3 activities are asking for creative solutions and outcomes (workshops, makers' areas, math board games). In that way, May Month of Mathematics is serving as the classical IBSE model, but also representing the excellent example for RRI practice in the domain of science education. Finally, both elements are incorporated into CREATIONS approach which is determined by this project.

5. Learning Activities & Effective Learning Environments

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: Mathematics and related disciplines **Relevance to national curriculum: Not directly connected but always serving as a support to regular teachers' activities.** **Class information** **Year Group: Primary and secondary schools** **Age range: 7-18** **Sex: both** **Pupil Ability: All pupils could participate**	**Materials and Resources** ***What do you need? (egg.*printed questionnaires, teleconference, etc.)** ❖ **exhibitions of interactive exhibits and visual representations** ❖ **movies, documentaries, cartoons with mathematical topics** ❖ **technical equipment : computers, projectors, smart boards, printers, audio-visual systems, internet** ❖ **workshop materials and consumables** ❖ **printed materials for interactive work** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** ❖ **central exhibition space, egg. science center, science museum or science club** ❖ **parallel settings in different venues** ❖ **scientific and educational institutions (research centers, institutes, faculties)** ❖ **schools** ***Health and Safety implications? None*** ***Technology? Computers, audio-video reproduction systems and internet.*** ***Teacher support?***

Prior pupil knowledge
As schools are reserving their visit slot in advance, while declaring class and age information, all programs are customized for the each group. In that way, the content they choose is correlated with their actual knowledge and abilities. However, their respective teachers are preparing pupils for their visits giving them basic information about the specific programs and activities. Sometimes, if requested, the complete scheduled could be arranged with a teacher.

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***
During this program, pupils will:
- **gain the basic knowledge about the chosen topic(s),**
- **understand relations between mathematical theories and practices,**
- **analyze the presence of mathematics in everyday life, including various artistic disciplines,**
- **investigate and research on their own, separately or/and in group,**
- **be inspired to ask questions and to critically discuss the content,**
- **produce creative outcomes as a result of workshop (activity),**
- **share their experiences with other pupils, friends, parents, relatives…**

Assessment	Differentiation	Key Concepts and Terminology
activity questionnaires **general questionnaires** **(as described in Section 7)**	*How can the activities be adapted to the needs of individual pupils?* All activities are adapted to the needs and knowledge of each group, in communication with school principal, representatives or respective teacher(s).	**Science terminology:** math, (math) applications, geometry, biology, physics, psychology, polyhedra, Pythagoras, Leonardo and other famous historic figures, contemporary famous mathematicians, equations, optimization **Arts terminology:** arts, architecture, visual mathematics, creativity, colors, shapes and forms, tiling, music, sound, rhytm

Session Objectives:
During this scenario, students will

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Engage with educator's questions. Watching different (interactive) materials and using web to explore specific topic or subject.	Strong support and guidance in order to attract the students' interest to specific math subject.	Drawing or making a model, use of arts as supporting system.
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	In this phase, pupils / students are taking over the leading role from the educator(s) until the end of the activity. Children's attitude should be playful and creative, not strict and rigid. They're just starting their quest for the answers and evidences…	In this phase, educator and teacher has the crucial role to directly inspire and guide children bringing them to the correct (necessary) starting point.	Arts models from the previous phase could be useful in the creative exploration process.

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Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Internal communication, critical thinking, open discussion.	Mediator if / when necessary, with participation of faculty students as engaded educators.	Limitless creativity as a way of research and investigation.
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Use of previous knowledge, not only from mathematics but also from other disciplines and activities. Development of interdisciplinary way of thinking.	Support and/or indirect assistance if children can't formulate reliable explanation.	Explanation might be presented through short video (made by phone camera), song or a poem, or any other basic artistic form.
Phase 5: CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Stimulation for the use of knowledge from other disciplines and from everyday life.	Teacher could remind students to the classes they've previously passed through.	
Phase 6: COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Team work in the preparation of final presentation, open dialogue at the end, mutual and individual remarks and conclusions.	Just supporting, without formal role.	Potential use of artistic mediums in the final presentation (with educator's guidance).

Phase 7: REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Personal or group reflections, comments and proposals for better understanding of IBSE process from pupils' or students' point of view.	Inspiration and support for personal or group reflections, comments and proposals.	Asking children to propose additional artistic content that could be useful in future IBSE activities.

6. Additional Information

Each edition of M^3 program has its unique visual identity and separate online presentation. However, all of them could be found (as archive) at http://www.cpn.rs/m3/.

For each year, informative materials are prepared and printed, in forms of posters, flyers, catalogues and brochures.

Each year, a famous international mathematician is a guest of honour of M3 program, with the translation of its popular science book into Serbian.

7. Assessment

Two kinds of evaluation being conducted during the previous M^3 programs. First of all, all of the organized activities with an audience (such as workshops and lectures) are being evaluated right after the activity, using specific questionnaires. Further more, the overall impressions are evaluated by a questionnaire any participant can fill any time during their visit to any segment of M^3 program. Also, the overall number of the participants is estimated.

What would be very useful, but so far out of our scope, is a research of the general population before and after the M3, to see if the general opinions of the mathematics as well as the number of students choosing mathematics as a career has changed. The positive fact confirming this is that the number of applications for the faculties of mathematics in Serbia is strongly rising for the last 3-4 years.

8. Possible Extension

Some segments prepared and produced under the auspices of M^3 program were already presented at regional level, particularly in several neighboring countries like Croatia, Bosnia and Herzegovina, Macedonia and Montenegro. There was a wide interest for the use or visit of some elements by partners in Romania, Hungary and even Georgia. We strongly believe that basic ideas, concept and content in general or divided to segments have strong potential on international level.

In few occasions, ideas and content of M^3 program were integrated into preparations of applications for different EU programs. Some of them, however, are still under consideration.

9. References

D3.2.86 SORTING DANCE - connecting programming and art by dancing activities

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Natalija Budinski	
Code:	D3.2.86.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator's Identity

1.1 Subject Domain

Programming, sorting algorithms

1.2 Type of Activity

- Educational activity based on Creativity - enriched Inquiry Based Approaches (school based)
- Both, in-school activity (workshops with students) and out of school activities (students giving workshops to other students and wider audience on scheduled events)

1.3 Duration

It consists of:

- two workshops in school,
- one public workshop (e.g. in Science Center or Science Museum)
- one evaluation workshop in the school (e.g. evaluating learning objectives and each phase of the process)

Each activity lasts 90 minutes. Preparation for each activity lasts 180 minutes.

1.4 Setting (formal / informal learning)

Settings of the activities were both formal and informal.

Formal activities were performed in the school, in the classroom equipped with computers, where students learned about basics in programming and sorting algorithms.

Also, evaluating activities were taken in school setting.

Informal activities were based on the public workshops presented by the students to wider audience or in institutions that support science promotion and education (e.g. in Serbia, the students' led workshop was held in school, but it was prepared for wider audience).

1.5 Effective Learning Environment

- Communities of practice
- Art-based
- Dialogic space/argumentation
- Visits to research center
- Communication of scientific ideas to audience

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2.Rationale of the Activity / Educational Approach

2.1 Challenge

Living in the present time, we are facing with digital revolution, which influenced almost every segment of our life. Due to that, programming become an important discipline that is started to be incorporated to many curriculums worldwide. By learning programming, in future students become creators of software, not just users. Maybe it is not that evident, but programming is not just about writing lines of code. Besides coding, successful programmers need to develop many other skills, such as collaboration, communication, problem solving, but also creativity. We need students that will develop software, programs or apps, based on understanding of human needs in order enhance our life in many aspects, such as economy, health or education. In order to that we need to develop students' computational thinking, rather than put stress on technical skills. Student need to know how to decompose a problem, design an algorithm or abstract the concept.

To achieve that we need to work on pedagogical strategies development. Maybe it is sounds as a surprise, but many concepts of computational thinking can be illustrated without computer. Learning programming without computer is challenging, but it can provide an opportunity for students to explore programming essentials and key concepts.

2.2 Added Value

During the in-school workshops students, we have analyzed the concept of sorting algorithms trough writing a program in computer language Python, but also trough dance and movement. Good results could be achieved by using dancing activities, connecting visual, spatial and structural aspect of sorting algorithm. The workshop aims to simulate a sort algorithm that is representative of computer. The dance is used for visualization and adding a physical picture of abstract notion of algorithms.

The out of school workshop for wider audience was based on the fact that the visualization and physical picture of algorithms can help participants to understand the process of writing codes. For that purpose, the participants were taking part in the dance. During the workshop, students have taught other present about Bubble sort algorithm.

3.Learning Objectives

3.1 Domain specific objectives

This workshop describes how to create a sort algorithm based on physical representation by dance. The workshops could be implemented in regular school lessons in addition to the usual way of teaching coding.
The domain specific objectives are:

- To explore and understand sorting algorithm
- To learn about programming language Python
- To revise their previous knowledge about computer science in new and different context
- To explore and understand the process of writing programs
- To explore bridges between virtual and physical reality
- Offer students possibility to present their work and teach others trough public activities

3.2 General skills objectives

The general skills objectives are:

- To develop interdisciplinary thinking and understanding among students and teachers and to help integration of conflicting insights from alternative disciplines such as arts and programming
- To develop scientific inquiry skills applying their knowledge in new situation and try to think in unconventional ways
- To develop communication and social skills by learning how to interact and dialogue with others during the public workshop
- To practice learning science trough IBSE steps

4.Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to enhance computational thinking by using dance in the process of creating a computer program. Also, the aim is to provide teachers with an open educational and outreach platform that will enable students to observe problems from different and unusual aspects.

We achieve this aim through:

- Exploration of sort algorithms
- Dancing activities
- Comparing approaches
- Complementing other educational activities for students such as public workshop

4.2 Student needs addressed

Based on quantitative and qualitative feedback from teachers and student, workshops address adequately the following students' needs:

- Interest in programming and computer science
- Thinking out of the box
- Sense of the fact that thing can be explored from different and unexpected aspects
- Evidence that computer science and programming has connection to many other aspects
- Exploration of different competences, talents and aspects of intelligence

5.Learning Activities & Effective Learning Environment

Science topic: Computer science **Relevance to the national curriculum:** Programming algorithm is in the national curricula as students in high school (gymnasium) have Informatics as a compulsory subject. ***Class information*** Year Group: High school students Age range: 14-18 The scenario allows adjustments so the students with various abilities can participate	**Materials and Resources** *What do you need* - Computer with programming language Python *Where will the learning take place? On site or off site? In several spaces?* - School classroom - Science festivals or similar events **Health and Safety implications?** None **Technology?** Computers with internet access and video-conferencing equipment **Teacher support?** Guiding the process; Preparation and Scaffolding

Prior knowledge

There is no need for prior knowledge in programming, the activities are organized from simple to more complicated tasks in order to help students follow the topic.

In the introduction session, the teacher should arouse students' interest to explore the topic. The prepared materials would be in both, electronic and paper format.

Individual session project objectives ***(What do you want students to know and understand by the end of the lesson?)***

The workshops have three segments: introduction to computer science and algorithms in general, programming a sort in Python and dancing algorithm. At the end of the lessons students should know how to write simple sorting algorithms.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Evaluation is done trough informal students' feedback and via formal assessment made by teacher	*How can the activities be adapted to the needs of individual pupils?* Learning about algorithms could be adjusted to the students' needs according their age, interest, previous knowledge and students personal strengths and competences. Instead of Python, other programming language with good pedagogical support can be used.	Science terminology: computer science, algorithms, sort algorithm, Python Arts terminology: dance, rhythm, music, body movement

Session Objectives:
During this scenario, students will explore:
- algorithms which are key concept of programming and computer science
- Bubble sort as an example of sorting algorithm
- physical representation of sorting by dance
- about the computer science, its importance and application
- about how universal reasoning is important when programming
- embark on dialogue and discussion with people who are not involved in learning process and share gained knowledge and experience

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 QUESTION: students investigate a scientifically oriented question	Balance and navigation is achieved trough teachers' mentorship and guidance with focus on dialog among students. While individual activity leads to greater sense of empowerment and agency, collaborative activities create trusteeship among group. Possibilities are being explored trough interdisciplinarity of the approach.	Students engage in a dialog with a teacher and each other about key concepts in the computer science.	Engage students with questions and tasks that will motivate them to explore this topic more and beyond the classroom. Provide additional materials and links for students who want to investigate topic by themselves. Research on the Internet about unusual ways of learning key concepts of programming.	Discover relation between science and dance.

Phase 2 EVIDENCE: students give priority to evidence	Students are exploring evidences and data coming from individual and collaborative activities such as practical work and collaboration. Risk, immersion and play are the most important in empowering pupils to look for evidences.	Students take part in workshops and learn about agreed sorting algorithm.	Organizing workshops, providing materials that will enable students to investigate and look for evidence.	Introducing students with dance that physically describe Bubble sorting algorithm
Phase 3 ANALYSE: students analyze evidence	While analyzing facts received in the workshops students engage in dialog with each other in order to make plan for further work which would be their future task. Empowerment and agency come from having control of the learning process - from the first phase which is asking questions to analyzing evidence.	Students analyze evidences trough learning about features of sorting algorithm.	Monitoring students work and providing help for the further tasks.	
Phase 4 EXPLAIN: students formulate an explanation based on evidence	The main idea is to play with possibilities in order to get new solutions and product of work.	Students are given a task to develop algorithm by computer or by dance. They need to consider different possibilities for explanation. Depending on students' preferences they can explore classical or artistic. Students use their knowledge of algorithms in order to use it in dancing activities and present this	Assist students in the process of their organization.	Dance preparation.

		topic later on at a public event.		
Phase 5 CONNECT: students connect explanations to scientific knowledge	Usage of miscellaneous ways of thinking, combining theoretical knowledge, dancing activities, music background clearly illustrate how is interdisciplinary knowledge gained in school. Making the sort algorithm as a program in Python and illustrating its by dancing leads to sense of empowerment and agency. Connecting explanations to scientific knowledge implies individual, collaborative and communal activities for a change.	Students make the sort algorithm. They work in the pairs or groups. Dancing activities need to be followed with the theoretical knowledge of algorithms.	Helps if there are some problems in the process.	Dance that combine movement, rhythm, music in aesthetically appealing way.
Phase 6 COMMUNICATE: students communicate and justify explanation	The way that the scientific knowledge acquired is communicated in this phase is based on dialog and interdisciplinary approach. Both students giving workshop and those who participate are immersed in the activity, taking risk and being ready to play with all possibilities that cooperation of art and science can bring.	Student holds a public workshop, teaching other students about Bubble sort fractal.	Teacher helps during the process of workshop organization.	Results of a workshop are recorded.

Phase 7 REFLECT: students reflect on the inquiry process and their learning	Activities dedicated to the reflection of the whole process trough individual and collaborative task that lead to the open-ended questions and possibilities for further exploration. Reflection leads to new dialog, new risks, opening new possibilities.	Students make proposals of further investigation of the topic.	Teacher summarizes results and make plans for the future.	Public performance of students' work.

6. Additional Information

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

8. Possible extension

This kind of approach can extend to other programming languages that students want to explore and learn.
Also, It is possible to use these activities to other programming algorithms – not just for array sorting.

9. References

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D3.2.87 BUILD YOUR OWN CITY

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Anica Tričković	
Code:	D3.2.87.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1.Introduction / Demonstrator's Identity

1.1 Subject Domain

Mathematics, Architecture

1.2 Type of Activity

- Educational activity based on Creativity - enriched Inquiry Based Approaches (school based)
- In-school activities – workshops with pupils during school hours
- Educational activities that promote school-research center collaboration (local workshops with architects eg.in Architectural faculty),
- Educational activities that promote school- STEM professional collaboration (international Skype session with an civil engineer)
- public presentations and workshops with exhibitions of 2d and 3d city models

1.3 Duration

Overall duration is 3 months

- Every week workshops with teachers in different classes – arts, technical modeling and mathematics – 45 to 90 min.
- One workshop with the architects – 90 min.
- Skype session with architect/civil engineer 30 minutes
- Workshop with science center or science institute, creation of 3d models using 3d printers or 3d pens – 120 min.
- Public exhibitions – various duration

1.4 Setting (formal / informal learning)

Settings of the activities were both formal and informal.

Formal activities were performed in the school, in the classroom during mathematics, art and technical modeling. Also, evaluating activities were taken in school setting.

Formal activities were also conducted as a workshop in Architectural faculty.

Informal activities were based on the public workshops presented by the students to other students in institutions that support science promotion and education (e.g. in Serbia, the students' led workshop was held in the Centre for the Promotion of Science in Belgrade).

1.5 Effective Learning Environment

- Art-based
- Dialogic space/argumentation
- Visits to research center
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Students in elementary school are often anxious to know 'How is this relevant to my life? Why do we need to learn this?', especially regarding mathematics. The problem lies with the fact that for the students' mathematical concepts seem very abstract and not-applicable in real life. With this project we wish to answer all these questions and show the students that what we learn in school can be used for solving real life problems and can be applicable in the world around them.

Challenge also lies in connecting several subjects, so that they can simultaneously process the same topics on classes, which leads to correction of curriculum plans and a lot of adjustments, which is very hard in a strict school system (a great challenge for schools in Serbia)

2.2 Added Value

The idea behind this project is to encourage students to develop and build their city. They will do this gradually, from simple to more complex models. Students will first make paper collages and art pieces of the cities, and then building models and city layouts. While working on this project, students will learn key mathematical and engineering concepts, which will help them in real-life situations. They will also learn about what a city needs to function properly and how a pleasant life style can be established for its residents. This is crucial for our future, because before the year of 2050., more than 60% of population will live in a large city.

This project allows students to do individual research and apply learned skills and geometrical knowledge while they solve problems and make decisions based on their knowledge, creativity and imagination. Pupils will use a lot of geometrical concepts e.g. Designing city parts using geometrical shapes, figures and models. They will involve also skills and knowledge from different subject at the same time.

The aim of the project is to focus on geometry, but it involves a lot of other elements which include IBSE learning, problem solving, cooperation, communication, individual learning etc. Project involves not only mathematical skills, but also involves components of social studies, drawing and painting, making of collages, technical drawing, recycling, research about social development, problem solving and understanding and communication skills.

Pupils of different age, knowledge, sex and abilities can participate in this project. They can enchase interest in mathematics and other STEM sciences, and maybe even choose to become an architect or an engineer, which will influence their future professional orientation.

3. Learning Objectives

3.1 Domain specific objectives

The aim of this project is to explore geometry through different interesting activities, which can connect mathematics and art. Workshops can be implemented during classes or as an individual project.

Domain specific objectives are:

- To get students interested in STEM subjects (Science, Technology, Engineering and Math)
- To teach them how can they apply their knowledge to a real life problems
- To show them how can they combine STEM with Art
- To introduce them to architecture and civil engineering
- To show them how to collaborate and work in team

3.2 General skills objectives

The general skills objectives are:

- To develop interdisciplinary connections and understanding between students and professors of various subjects, and integration between art and mathematics
- To develop creativity, critical thinking, communicational and social skills with group work, team learning through IBSE and applying their knowledge in new scenarios
- To develop public performance, interactions and dialog with students during public workshops
- To practice learning science trough IBSE steps

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to enable students to explore and develop different aspects of competences by using art to understand scientific approach in mathematics and architecture. Also, the aim is to provide teachers with an interactive, open educational and outreach platform for inspiring and engaging young students with the mathematics and art.

We achieve this aim through:

- Exploration of mathematical and geometrical concepts in 2d and 3d
- Hands-on activities
- Exploration of aesthetics concepts
- Complementing other educational activities for students such as public workshop

4.2 Student needs addressed

Based on quantitative and qualitative feedback from teachers and student, workshops address adequately the following students' needs:

- Interest in mathematics and art, as well as other STEM disciplines
- Active participation in all activities, their individual and group research, critical thinking and arriving at conclusions
- Evidence that mathematics is useful and applicable
- Exploration of different competences, talents and aspects of intelligence, because in this activities can be done by students with all levels of knowledge and skills

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5. Learning Activities & Effective Learning Environments

Science topic: Mathematics **Relevance to the national curriculum:** Application of knowledge in geometry in plane and space, properties of geometric figures and bodies, calculation of scope, surface, volume; proportions, symmetry, similarity ***Class information*** Year Group: elementary school students Age range: 11-14 The scenario allows adjustments and adaptations so the students with various abilities can participate	**Materials and Resources** *What do you need* - Computer with access to the internet, projector, paper, scissors, glue, pencils, 3d printer/3d pens, crayons, paint…. *Where will the learning take place? On site or off site? In several spaces?* - School classroom - Science centres and museums - Science festivals or similar events **Health and Safety implications?** None **Technology?** Computers with internet access and video-conferencing equipment, 3d printers / 3d pens **Teacher support?** Guiding the process; Preparation and Scaffolding

Prior knowledge

Some prior knowledge is needed.

The main goal of these activities is to create a real context for applying knowledge about geometric objects and their properties. Activities are organized from simple to more complex tasks to help students of different ages and abilities. During this process, students can restore their knowledge of the scope, surface, volume, proportions, size, and properties of polygons, geometric figures and bodies, angles, transformations, Pythagoras theorem, symmetry, and many other topics that have been learned earlier in mathematics.

Individual session project objectives ***(What do you want students to know and understand by the end of the lesson?)***

The project was realized through the following workshops (these are guidelines, and can vary in details depending on which scientist to call, in which institution to organize some wokrshops etc):

- Geometrical paper collages – Students are making paper collages of made-up cities, using two-dimensional figures already familiar to them, e.g. triangles, rectangles, polygons, circles etc. These are dependent on the age and knowledge of the participants. The collages were used to determine the level of knowledge amongst students, via calculating materials, circumference, height etc.
- Art form of cities – this workshop was used to present their cities by connecting geometry and art. Most of their effort went on painting city background, adding interesting details using their imagination, and they learned about colors, shapes, different forms and contrast.
- Brainstorming – Students were figuring out the best way to make 3d models of cities – which geometrical figures they can use, and which knowledge form mathematics and other subject is going to be needed for this process. Main questing in this phase were: What is a city? What are all the things and objects a city should need for proper functioning? What are self-sustaining cities? How will future cities look like?
- A visit to Architectural faculty – Here we asked for answers to our questions from professors and assistants from the faculty. With a lot of examples of city-layouts and ideal solutions for real problems form the region, students learned a lot about their next steps. Professors were there to help about techniques for city modeling (today, mainly via different software) and about main features of self-sustaining cities and communities. They were helpful about choosing the proper ratio of the models.
- Session with an engineer – Skype talk with an engineer was a great solution for finding out more hand-on information about sustainability of a city, about power regulations etc. This was very useful because we gathered a lot of information about modern windmills (all using Microsoft Educational programme 'Skype a scientist'). Amongst other, students had the opportunity to learn about parts, size and mechanism of windmills, but also about consequences of a lightning strike and how to minimize them.
- Making a city model – Students study the dimensions of buildings, proportions and scale to be used, test and draw object grid, after which they decorate and glued them together. Its good to encourage students to use recycled materials as much as possible (newspaper, cake packaging, tea and medicine packaging, soda cans, Styrofoam remains, ...). Students calculate how much material they needed by using mathematical knowledge and everything they learned during the project so far. It is good to focus on the things that every city should

have, i.e. downtown with buildings for big companies, a mall, a school, a church, residential area, green areas with parks and ponds, and areas for sport and recreation, as well as sources of renewable energy (solar panels and 3D printed windmills).

- Peer workshop - Students who are participating in the project are helping their peers through the 'Making a paper city workshop'. Students present their works so others can get inspired, they also there to help their peers and guide them in making their paper collage easier and faster, to help them calculate how much material is needed and also help them in designing and drawing.
- 3D pen workshop - Student learn how to use 3D pens and with the assistance of science center volunteers, students build houses. Students learn that they need different parts that are drawn separately and then assembled together. They need to work in teams, assign tasks, draw their parts on paper first and then fill them in with 3D pens.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Evaluation is done through informal students' feedback and via formal assessment made by teacher	*How can the activities be adapted to the needs of individual pupils?* Activities can be adjusted to the students' needs according their age, interest, previous knowledge and students' personal strengths and competences, because they are divided and sorted based on complexity	Science terminology: mathematics, application of mathematics, geometry, scope, surface, volume, proportions, dimensions, angles, geometric shapes and bodies, symmetry, similarity ... Arts terminology: art, architecture, visual arts, creativity, colors, shapes, forms, contrast, fantasy

Session Objectives:
During this scenario, students will explore:
- geometry in plane (lines, angles, triangles, quadruples, circles, polygons ...)
- geometry in space (polyhedral - prisms, pyramids, ...)

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- mathematical properties of geometric objects and connection with previously acquired mathematical knowledge (algebra, application of Pythagorean theorem, finding volume, surface, volume, scale, proportions, symmetry, similarity ...)
- aesthetic value of geometric images, collages and models
- activities that help students understand geometry
- about science, engineering and technology involved in the construction of cities
- will talk with experts in these areas who will assist them in the realization of the project
- about how science and mathematics encourage art and, if possible, vice versa
- to share the learned knowledge and start a discussion with people who are not involved in the learning process with who students can share acquired knowledge and experience

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONS Features**	**Students**	**Teacher**	**Potential Arts Activity**
Phase 1 QUESTION: students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in	Students engage in a dialog with a teacher and each other about application of previously learnt mathematics phenomena. They create and choose questions which will help them and guide them to wishing results during learning through problem solving. Possible questions are: what is needed to create a city? How can you make 2d	Helps students in shaping questions and solving problems, while enriches students' creativity so they can be more successful in problem solving	Making drawings and collages using creativity and art

	experimental design and collaborative work, as well as in the initial choice of question.	model, and how a 3d model of a city? Which knowledge from mathematics do we need? What is needed for a city to function properly? How can you present a city using art? Which materials can we use? How can a city be self-sustainable?		
Phase 2 EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students through fun activities research about possible solutions and seek for answers to questions from the previous phase.	Organizing workshops, providing materials that will enable students to investigate and look for evidence, enable contacts with the professionals and institutions which can help students during the project.	
Phase 3 ANALYSE: students analyze evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	In different groups through cooperation, students are analyzing gathered facts and try to apply their knowledge to city models.	Mathematics teachers helps students to connect knowledge needed for the construction of models with mathematical knowledge.	**Making of first 2d models**

			Arts teaches helps them to apply creativity into their work and to enrich their aesthetical value.	
Phase 4 EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Based on gathered facts and arguments, students try to give their explanations about the topic, and try to figure out next steps.	Teachers guide and overview group activities and articulate group discussions.	
Phase 5 CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	In this phase, students are connecting their knowledge from different subjects needed for the successful realization of the project, they develop scientific argumentation and upgrading researched facts	Teachers guide and overview group activities and articulate group discussions..	
Phase 6 COMMUNICATE: students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	In this phase, students are exchanging conclusions and continue building models.	Teachers guide and overview group activities and articulate group discussions..	Creations of 2d and 3d models

Phase 7 REFLECT: students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Students discus their models, city ideas, ..flow of the project	Teacher articulate discussions	Public exhibitions

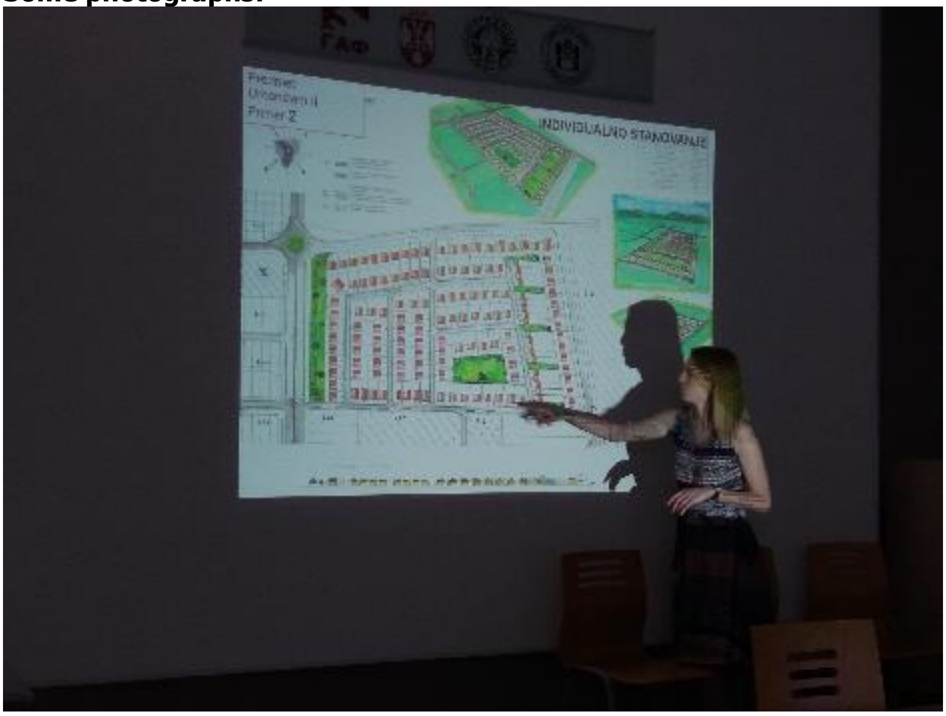
6. Additional Information

This link contains photograft from all stages of the project
https://1drv.ms/f/s!AhEaBkXi3stxlgoLfwLzpCy14J9f

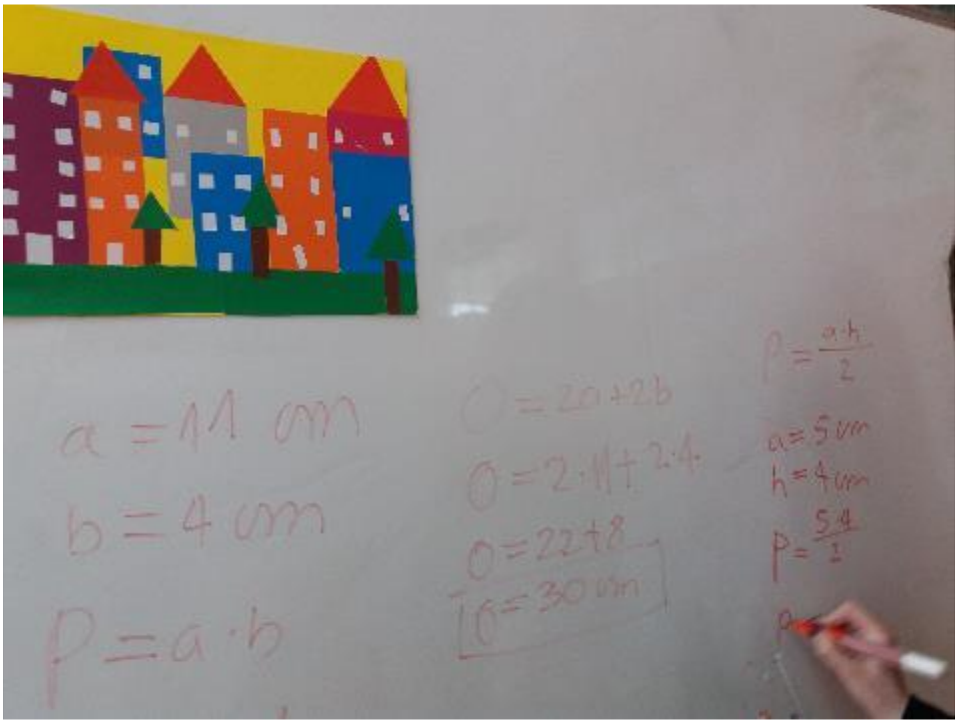
Sway presentation of all activities https://sway.com/IpRIjzW3S8plbKPV

Skype a scientist https://anicatrickovic.weebly.com/my-skype-blog/skype-a-scientist-with-an-engineer

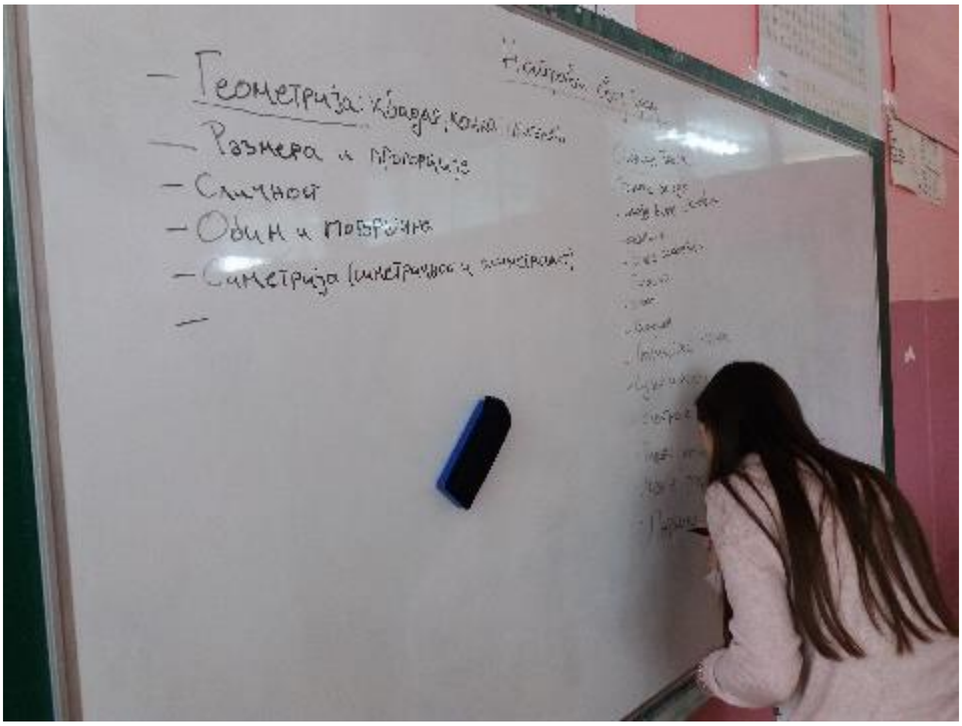
Some photographs:



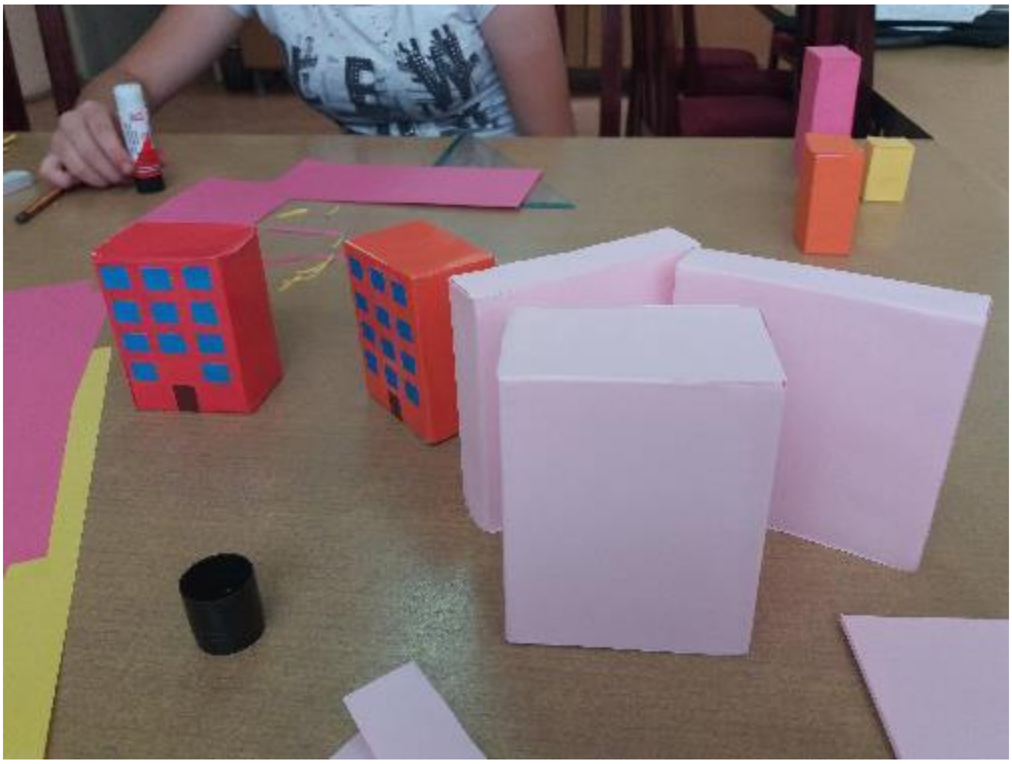
Visit to Architectural faculty



Connecting mathematics and art



Brainstorming



Model making

Peer workshop


3d pen workshop

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

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8. Possible extension

- With adding a little history, students can make cities from different regions and historical epochs, e.g. - ancient cities, cities in the middle ages, Victorian cities, future cities etc.
- If the proportion of the city is enchances (our original one was 1:200), students can show some features with more details, some areas, buildings and objects, as well as traffic areas and vehicles.
- Google Map tool can help by showing the real city, or its part, so the project can be turned into a modeling of an existing city with communication about properties and improvement.
    - If there are parts of students' hometown they are not pleased with, there is a possible solution like going to the authorities with a better idea, and with the models, and maybe take some action to help improve the surroundings and environment

- ## 9. References

Buildings and architecture art lessons https://www.deepspacesparkle.com/category/art-lessons-by-subject/buildings-and-architecture/

Scale and proportion in architecture http://talkarchitecture.in/scale-and-proportion-in-architecture/

The Global Goals (Sustainable development goals) https://www.globalgoals.org/11-sustainable-cities-and-communities

Sustainable Cities and communities UNDP www.undp.org/content/undp/en/home/sustainable-development-goals/goal-11-sustainable-cities-and-communities.html

Skype-a-Scientist at Microsoft Education platform https://education.microsoft.com/skypeascientist

D3.2.88 DRAGON CURVE - connecting math and art in classroom by teaching fractals

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:** Natalija Budinski	
Code:	D3. 2. 88	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator's Identity

1.1 Subject Domain

Fractals, Mathematics

1.2 Type of Activity

- Educational activity based on Creativity - enriched Inquiry Based Approaches (school based)
- Both, in-school activity (workshops with students during the mathematics class) and out of school activities (students giving workshops to other students on a science fair or similar events; public exhibition of fractal origami pieces made by students)

1.3 Duration

It consists of:

- two workshops in school,
- one public workshop (e.g. in Science Center or Science Museum)
- one evaluation workshop in the school (e.g. evaluating learning objectives and each phase of the process)

Each activity lasts 90 minutes. Preparation for each activity lasts 180 minutes.

1.4 Setting (formal / informal learning)

Settings of the activities were both formal and informal.

Formal activities were performed in the school, in the classroom equipped with computers, where students learned about fractals and their mathematical properties. Also, evaluating activities were taken in school setting.

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Informal activities were based on the public workshops presented by the students to other students in institutions that support science promotion and education (e.g. in Serbia, the students' led workshop was held in the Centre for the Promotion of Science in Belgrade).

1.5 Effective Learning Environment

- Communities of practice
- Art-based
- Dialogic space/argumentation
- Visits to research center
- Communication of scientific ideas to audience

2. Rationale of the Activity / Educational Approach

2.1 Challenge

Fractals are usually connected with modern and advanced mathematics. The father of fractals, Mandelbrot, described them as: "beautiful, damn hard, and increasingly useful". What is more interesting, they can be found everywhere in nature, which is practically full of fractal patterns. Fractals have become an inspiration for mathematical art, so the topic of fractals is not strictly connected with mathematics and science.

Fractal geometry is getting significant attention in the scientific world, but these types of lessons are not recognized in the curriculums of most schools in the countries worldwide.

Even though many educational researches are providing evidence of benefits of teaching science trough art, this practice is uncommon in the classroom. On one hand, it is understandable, because teachers are reluctant to work beyond the curriculum and without official support, but on the other hand, only a small artistic content in the mathematical lesson can make huge and beneficial impact on the educational process, especially in terms of increasing motivation among students for engaging in science.

2.2 Added Value

Bringing fractal geometry into the classroom can be done by expanding some usual activities and lessons in the schools. Morover, by teaching fractals, new directions in education might appear. Fractals connect mathematics, art and science, and therefore their application in teaching and learning could contribute to develop different aspects of competences. Students may gain interest in mathematics via art, and vice versa which may direct their future carriers.

The visual expression of fractals can convey mathematical concepts, such as geometric shapes and structures, symmetry, iterative and recursive forms, structures or changes can be taught with modeling and explaining fractals. Also, fractals have eye appealing forms, which can inspire students in art exploration. Although fractals are very complex, they are easy to make with a repetition of forms, and hands-on activities could improve manual abilities of students, which are highly neglected due to increased use of technology.

During the in-school workshops students, who were without previous mathematical knowledge of fractals, were introduced to their definition and properties. Good results could be accomplished by using hand-on activities and paper folding, connecting esthetical and mathematical aspects of fractals. The out of school workshop was based on the fact that the visual representation and hands-on activities can aid the participants in discovering fractals without formal definitions and concepts. For that purpose, the participants

were given paper to fold the dragon curve. Their work was exposed in Centre for science promotion during their public workshop. During the workshop, students have taught other present about fractals and how to fold one from paper strips.

3. Learning Objectives

3.1 Domain specific objectives

This workshop describes how to investigate fractals with the help of hand-on activities and paper folding. Described activities can be used for exploring the fractal phenomena and connections between mathematics and art. The workshops could be implemented in regular school lessons as an alternative to classical geometry.
The domain specific objectives are:

- To explore and understand fractal phenomena
- To learn about contemporary mathematical achievements
- To revise their previous mathematical knowledge in new and different context
- To explore and understand application of mathematics in practice, not just theory, through hands-on activities
- To explore bridges between mathematics and art
- Offer students possibility to present their work and teach others trough public activities

3.2 General skills objectives

The general skills objectives are:

- To develop interdisciplinary thinking and understanding among students and teachers and to help integration of conflicting insights from alternative disciplines such as arts and mathematics
- To develop scientific inquiry skills applying their knowledge in new situation and learning about advanced mathematical concepts
- To develop communication and social skills by learning how to interact and dialogue with others during the public workshop
- To practice learning science trough IBSE steps

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to enable students to explore and develop different aspects of competences by using art to understand scientific phenomena like fractals. Also, the aim is to provide teachers with an interactive, open educational and outreach platform for inspiring and engaging young students with the mathematics and art.

We achieve this aim through:

- Exploration of mathematical properties of fractals
- Hands-on activities

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- Exploration of aesthetical properties of fractals
- Complementing other educational activities for students such as public workshop

4.2 Student needs addressed

Based on quantitative and qualitative feedback from teachers and student, workshops address adequately the following students' needs:

- Interest in mathematics and art
- Curiosity about contemporary mathematical achievements
- Sense of the fact that mathematics belongs to the scientific enterprise
- Evidence that mathematics is useful and applicable
- Exploration of different competences, talents and aspects of intelligence

5. Learning Activities & Effective Learning Environments

Science topic: Mathematics **Relevance to the national curriculum:** Fractals are not on the national curricula as a separate lesson, but the topic and activities are related with mathematical contents in the curriculum, such as: Pythagoras theorem, logarithms, symmetry, etc. ***Class information*** Year Group: High school students Age range: 14-18 The scenario allows adjustments so the students with various abilities can participate	**Materials and Resources** *What do you need* - Computer with access to the internet, projector, paper, scissors, glue, pencils *Where will the learning take place? On site or off site? In several spaces?* - School classroom - Science centres and museums - Science festivals or similar events **Health and Safety implications?** None **Technology?** Computers with internet access and video-conferencing equipment **Teacher support?** Guiding the process; Preparation and Scaffolding

Prior knowledge

While there is no prior knowledge of fractals needed, the activities are organized from simple to more complicated tasks in order to help students follow the topic.

In the introduction session, the teacher should arouse students' interest to explore the topic. The prepared materials would be in both, electronic and paper format.

Individual session project objectives ***(What do you want students to know and understand by the end of the lesson?)***

The workshops have three segments: introduction to fractals, researching their mathematical properties and discovering their universal natural and artistic beauty. For that purpose, we have based hands-on activities on one particular fractal called the dragon curve fractal.

Besides the definition of the fractals, students should learn other mathematical features. During that process they could revise Pythagoras theorem, logarithms, symmetry etc., which they have previously learned in math classes.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Evaluation is done trough informal students' feedback and via formal assessment made by teacher	*How can the activities be adapted to the needs of individual pupils?* Learning about fractals could be adjusted to the students' needs according their age, interest, previous knowledge and students personal strengths and competences	Science terminology: fractals, symmetry, dragon curves, self-similarity, dimension, paper folding, valley folding, mountain folding Arts terminology: craftwork**,** art inspired with fractals and self-similar forms, modern art,

Session Objectives:
During this scenario, students will explore:
- fractals which are advanced mathematical concept
- mathematical properties of fractals and connect to previously gained math knowledge
- aesthetical properties of fractals and discover its artistic features
- hands on activities which help students in profound understanding of fractals

- about the science, engineering and technology involved in fractals
- about how science inspire art and if it is possible to do vice versa
- embark on dialogue and discussion with people who are not involved in learning process and share gained knowledge and experience

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONS Features	Students	Teacher	Potential Arts Activity
Phase 1 QUESTION: students investigate a scientifically oriented question	Balance and navigation is achieved trough teachers' mentorship and guidance with focus on dialog among students. While individual activity leads to greater sense of empowerment and agency, collaborative activities create trusteeship among group. Possibilities are being explored trough interdisciplinary of the approach.	Students engage in a dialog with a teacher and each other about application of previously learnt mathematics phenomena in understanding fractals.	Engage students with questions and tasks that will motivate them to explore this topic more and beyond the classroom by asking them to search for and recognize fractals around them. Provide additional materials and links for students who want to investigate topic by themselves. Tackle students with the questions and problems that illustrate fractals, both in scientific and artistic side of fractals.	Introducing students with art pieces inspired with fractals. Showing the real life examples that fractals occurred in nature.

Phase 2 EVIDENCE: students give priority to evidence	Students are exploring evidences and data coming from individual and collaborative activities such as practical work, calculations or research. Risk, immersion and play are the most important in empowering pupils to look for evidences.	Students take part in workshops and learn about mathematical properties of fractals.	Organizing workshops, providing materials that will enable students to investigate and look for evidence.	Mathematical properties of fractals such as self-symmetry has also an aesthetical component and artistic value.
Phase 3 ANALYSE: students analyze evidence	While analyzing facts received in the workshops students engage in dialog with each other in order to make plan for further work which would be their future task. Empowerment and agency come from having control of the learning process - from the first phase which is asking questions to analyzing evidence.	Students analyze evidences trough learning about mathematical features of fractals. Students should notice that they can use much of knowledge previously learned.	Monitoring students work and providing help for the further tasks.	
Phase 4 EXPLAIN: students formulate an explanation based on evidence	The main idea is to play with possibilities in order to get new solutions and product of work.	Students are given a task to apply their knowledge about fractals. They need to consider different possibilities for explanation of fractals. Depending on students' preferences they can explore mathematical or artistic way of presenting fractals.	Assist students in the process of their organization.	Hands-on activities that will lead to physical models of fractals.

		Students use their knowledge of fractals in order to use it in hands-on activities and present this topic later on at a public event.		
Phase 5 CONNECT: students connect explanations to scientific knowledge	Usage of miscellaneous ways of thinking, combining theoretical knowledge, hands-on activities, art background clearly illustrate how is interdisciplinary knowledge gained in school. Making models of dragon curves, based on the previously gained knowledge about fractals leads to sense of empowerment and agency. Connecting explanations to scientific knowledge implies individual, collaborative and communal activities for a change.	Students make models of dragon curves. They work in the pair. Hands-on activities need to be followed with the theoretical knowledge of fractals.	Helps if there are some problems in the process.	Models of dragon curves should be done aesthetically appealing, in different colors or techniques.
Phase 6 COMMUNICATE: students communicate and justify explanation	The way that the scientific knowledge acquired is communicated in this phase based on dialog and interdisciplinary approach. Both students giving workshop and those who participate are immersed in the activity, taking risk and being ready to play with all possibilities that cooperation of art and science can bring.	Student holds a public workshop, teaching other students about fractals.	Teacher helps during the process of workshop organization.	Results of a workshop on fractals are displayed in different colors and shapes.

Phase 7 REFLECT: students reflect on the inquiry process and their learning	Activities dedicated to the reflection of the whole process trough individual and collaborative task that lead to the open-ended questions and possibilities for further exploration. Reflection leads to new dialog, new risks, opening new possibilities.	Students make proposals of further investigation of the topic.	Teacher summarizes results and make plans for the future.	Public performance of students' work.

6. Additional Information

The activities related to teaching students about fractals has been extended and connected with other scientific fields such as programming. Lessons and tasks related to fractals were adjusted to the learning programming in Scratch. That is why we have collaborated with The Faculty of Electrical engineering at The University of Belgrade. During the visit, students who have previously took part in math-art activities, have a chance to talk to scientist, researches and students at this faculty and found out where they can use their high school knowledge. Also, this approach was presented at the 22nd Asian Technology Conference in Mathematics (ATCM 2017).

CREATIONS has received funding from the European Commission HORIZON2020 Programme


CREATIONS
Developing an Engaging Science Classroom

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

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8. Possible extension

This kind of activities can be applied to teaching students about other fractals and its properties such as Koch snowflake or Mandelbrot's fractal.
Also, it can be adjusted to teaching students about basics of programming. For that purpose, Scratch can be used as a suitable computer language.
It can be worked on teaching students how to code but include different art activities such as paper folding or dancing.

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https://www.youtube.com/watch?v=c-XxSfUzHGY

D3.2.89 PEER FORCE – Peer learning with audience interaction

Project Reference:	H2020-SEAC-2014-1, 665917	**Author**: Jelena Mijatovic (CPN)
Code:	D 3.2.89.	**Contributors:**
Version & Date:	v1.0 June 7th 2017.	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Demonstrator was primarily intended for Physics, Mathematics, Chemistry and Biology, but is applicable for all sciences.

1.2 Type of Activity

Educational activity based on Creativity - enriched Inquiry Based Approaches (school based) with performances of various types (closed school performances and/or public performances outside of school, e.g. in a Science Club/Center)

1.3 Duration

Overall duration is around 2 months. It includes preparation of the performance, rehearsals and the actual performance. Duration can be shortened or prolonged, depending on school activities, teachers and students who are participating.

- 2 months (time for preparation of the performance and rehearsals)
  - Up to 90 minutes (time for meetings and rehearsals)
  - Up to 30 minutes (duration of the performance)

1.4 Setting (formal / informal learning)

Formal and informal – rehearsals and preparations are conducted in school, but in workshop-like and more comfortable environment.

Informal – performance can be held in school's theater and/or in a Science Club/Center

1.5 Effective Learning Environment

- Communities of practice
- Art-based
- Dialogic Space / argumentation
- Visit to research centres (virtual/physical)
- Communication of scientific ideas to audience
- Experimentation (Science laboratories and eScience applications)

2. Rational of the Activity / Educational Approach

2.1 Challenge

- Due to extensive curriculum and lack of time during school hours, this kind of approach rarely finds its way into science classroom
  School system in Serbia leaves almost no space for teachers to expand or modify the way of STEM teaching. This results in lack of motivation for participating in this or similar activities, both in teachers as in students. Every engagement is done during off-school hours, in their free time, which also brings out complications in time management. It's a challenge organising the teacher and a group of students for a meeting/rehearsal while honouring their other engagements (e.g. sports, music school, language lessons etc).

- Embracing the concept of embodied learning
  Through this scientific performance, students were representing each concept/object with their body, as if it was alive. During preparation, it was hard for them to grasp this concept, so additional guidance through the process was needed.
  This kind of approach is somewhat playful and fun, as much as it is full of new information and concepts which students can easily grasp. This may cause some students not to take this approach seriously, and not to participate in important learning activities. Support and formal/strict guidance from classroom teacher is crucial.

- Concept of peer learning
  Challenge in peer learning can emerge both in students and in teachers. Some students can find it difficult to try and pass on knowledge. On the other hand, some students find it hard to learn from their peers, because they are of same/similar age, and could not find them seriously enough.
  Challenge for the teachers can lie in activities where students pass on knowledge, where they have to guide the students, and not participate in passing on the knowledge – where they have to leave it to the students to figure out the correct way to react to their peers and communicate science on the spot.

2.2 Added Value

- PEER FORCE demonstrator is connected with the Learning Science Through Theater demonstrator, and they share some values – especially the concept of embodied learning.
  Through the principles of embodied learning, basic principles of epistemological knowledge and pedagogical theories can be combined, so that the student can utilize his body as a source of knowledge and feel alive and active during the learning process. As a result, the seemingly absent student's body can be activated and used as a communication channel between students. (Arvola, Orlandre & Per-Olof Wickram's In Alsop, 2011).Through embodied learning, each time the human motor-sensory system is involved with his body movements, the stimuli he perceives can be converted into a more stable and powerful memory and cognitive representations (Abrahamson, Gutiérrez, Charoenying, Negrete, & Bumbacher, 2012).
  Embodied learning has been linked with the field of Science (Smyrnaiou & Kynigos, 2012). According to Hutto et al. (2015), embodied learning enhanced the understanding and acquisition of skills in physics, technology, engineering and mathematics. Gallagher & Lindgren (2015) investigated the advantages of physical representation of transfer (Chun Hung, Hsiu-Hao Hsu, Nian-Shing Chen, 2015) and found that its representation facilitates the learning outcomes more than just reading the transfer. Furthermore, Lozano and Tversky (2006) argue that gestures can facilitate learning, as they are considered as embodied knowledge. Finally, Novack & Goldin- Meadow (2015) argue that even the gestures can be incorporated into educational activities, especially in courses with symbols, such as Mathematics, Physics and Chemistry. Thus, pupils directly connect their movement, gesture and communication with scientific concepts which they perceive, as embedded in the educational activities (Kynigos, Smyrnaiou & Roussou, 2010; Smyrnaiou, Z., Sotiriou, M., Sotiriou, S. & Georgakopoulou, E. Multi- Semiotic systems in STEMS: Embodied Learning and Analogical Reasoning through a Grounded- Theory approach in theatrical performances. Journal of Research in STEM Education, Vol. 14, 2017; Menelaos Sotiriou, Vasiliki Grigoriou, Zacharoula Smyrnaiou, Evangelia Petropoulou (NKUA) – Learning Science Through Theater demonstrator, 2016).

  Additional added value:
- PEER FORCE provides much more informal and creative environment for learning about physics. During project activities students have the opportunity to question and apply knowledge gained in classroom. They learn how to conquer challenge before them – proper representation of that knowledge for their fellow students.
- Activities in the beginning of the project are workshop-like, and they allow students to work on their teamwork and communication skills.
- This kind of approach allows students ownership of the learning process, because they are actively involved in every step of project, in almost every concept, and they decide what is the best way to learn, inquire and then represent knowledge.
- Performance outside of the school can add stimulus for some students. The project gains greater importance, because the main event is performed publicly, for audience that is wider than their school and its students.
- PEER FORCE is designed to be interactive. During performance students are, besides acting, engaging the public in discussion about principles and behaviors they witnessed. This way the public

is involved in the performance at the end of each scene, and gets to experience certain topics in an unusual and interesting ways, and learn in the process.

- Peer learning allows students to learn from their peers. Values in this lie in passing on the knowledge from students similar age – they have the capacity to communicate in the language of other students, where they can communicate science in an informal way, easily understandable by other students.

  Other values are in connecting between students who pass on knowledge and students who are learning from peers, and forming peer bonds. This kind of connection between students is usually formed faster that the bond between teacher/adult and students, and can enhance and speed up the learning process.

3. Learning Objectives

3.1 Domain specific objectives

Main objective of PEER FORCE is to create opportunities for pupils to visualize, demonstrate and express a scientific topic from school curriculum, as well as learn from peer students in a fun and easy manner, in a way that is chosen by students and is understandable for their age and level of knowledge. With guidance from the teacher pupils will:

- Perform a Scientific play, based on selected theme form school curriculum (connected with the Learning Science Through Theater demonstrator)
- Explore through tasks about certain topics (individual and group effort)
- Learn how to connect raw theory with everyday occurrences, and how to visualize and communicate laws of natural sciences through art-based performance
- Gain deeper understanding of the effects and interaction of selected theme
- Experience the process of creating a theater-like performance, writing a script, preparing the costumes, scenography, and behaving on the stage
- Understand the principals of teaching and motivating students for inquiry based learning
- Experience the process of teaching and evaluating students / experience the process of being taught and evaluated by students

3.2 General skills objectives

- Embodied learning
- Engaging in interdisciplinarity: connecting STEM classroom with art
- Developing creative and critical skills
- Developing better cooperation and teamwork skills
- Improving communication skills
- Concurring the fear of performance

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Aims of PEER FORCE DEMONSTRATOR are to:

- Create an art-based platform for teachers, which they can implement into their classes
- Encourage students to use art and body movement to learn and spread knowledge – Spread the concept of embodied learning
- Engage students in Physics, Mathematics, Chemistry and Biology – and all sciences
- Encourage students to teach and to learn from each other – peer learning
- Connect school system with the research community/research institutions

4.2 Student needs addressed

Activities in PEER FORCE are conducted in *comfortable and creative environment,* not in form of a class, but as a series of discussions, assignments and through experimental/practised stage performance. Students are *participating* in the learning process, and it gives them more opportunity and courage to *express* their opinion, thoughts and findings more openly than in classroom.

Some of activities are in form of a *personal and group investigation*. This allows students to find a most suitable way to work on assignments, and also straightens their spirit for *teamwork* and cooperation.

For students, PEER FORCE represents a *new way of learning and understanding* a scientific phenomenon, so it is crucial that students have *guidance through the process of creating a scientific stage performance, and through connecting science with art*. Guidance was provided by the teacher and an arts consultant.

By the end of PEER FORCE students have gathered great *capacity to communicate science*. The knowledge they gained is very clear, this kind of learning process allows them to understand scientific process from different angles, along with different occurrences in everyday life. With understanding of science and with the understanding of other students of similar age or knowledge, students that participated in PEER FORCE can successfully represent that knowledge to fellow students, in a way that is interesting and fun, and adjusted to them.

5. Learning Activities & Effective Learning Environments

Science topic: **Physics, Mathematics, Chemistry and Biology** Relevance to national curriculum: **Physics, Mathematics, Chemistry and Biology primary school curriculum** Class information Year Group: **5th to 8th grade** Age range: **11-15** Sex: **both** Pupil Ability: **All pupils could participate**	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Materials for scenery and costumes** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Preparations for the performance is to take place in school (in ceremonial hall and classroom).** **The performance should take place in school's ceremonial hall and/or at Science Club/Science Center.** *Health and Safety implications?* **None** *Technology?* **Depends on each performance and arrangements between teacher and the students if they want music or slide show during their performance. Possible technology requirement would be projector, laptop, speakers** *Teacher support?* **Science teacher is there to explain every scientific phenomena during the process, train students for teaching, to paticipate in the process of creation and to evalute the performance. There is also an art counselor to help mediate between arts and science.**
Prior pupil knowledge - Basic knowledge about science phenomena	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

Project PEER FORCE can be realized through following stages:

Stage 1: *Students are familiarized with the concepts of embodied learning, art and science, IBSE and PEER FORCE. They've filled out first round of questionnaires (for later assessment). Teacher and students have an agreement about scientific topic from school curriculum, which they wish to perform about. Students have finished their research about scientific topic.*

Stage 2: *Group visit to research center/interactive exhibition/science museum, related to the scientific topic, which allows students to gain deeper understanding about explored scientific topic*

Stage 3: *Students finished writing a script for the scientific performance, with help and guidance from art consultant and teacher.*

Stage 4: *Students are familiarized with the concept of IBSE teaching. They at this point had a 'teaching' themed workshop with the teacher, and practiced on one another*

Stage 5: Rehearsals – *This stage is to last couple of sessions* ***–*** *During this stage, students, teacher and art consultant are agreeing on the proper stage and costumes*

Stage 6: *Preparation of the scenography and costumes is finished (students with teachers help)*

Stage 7: *Main performance is finished. At the end of this stage students who participated in the project have filled second round of questionnaires (students who performed and students who were in public have different set of questionnaires)*

Stage 8: *Assessment and evaluation - teacher, art consultant and school phycologist*

Assessment	**Differentiation**	**Key Concepts and Terminology**

Evaluation is done through informal students' feedback and via formal assessment made by *teacher*	*How can the activities be adapted to the needs of individual pupils?* **All activities are adapted to pupils needs and knowledge.** **Activities are divided by student interest. For example: some are talented for acting, some for the creation of concepts in a play and don't want to act, so everybody is participating in way that is best suited for them.**	**Science terminology:** ***Physics, Mathematics, Chemistry, Biology*** **Arts terminology:** ***scenery, costumes, script, body movement, performance***
Session Objectives: ***During this scenario, students will gain deeper understanding about the scientific phenomenon from curriculum which they are performing. They will be able to communicate and explain that topic to the public with the same or less prior knowledge.***		
Learning activities in terms of CREATIONS Approach		

Demonstrator of PEER FORCE is divided into two parts (by the type of participation) and some learning activities are achieved dually. Students who are participating can be divided as followed:

1. Group of students who is participating in creative process and performing
2. Group of students who is learning through the creative performance of peer students

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	*Dialogue* between teacher and students, about the scientific topic assigned to them. Teacher provides *Balance and navigation* through the dialogue and the process of investigation, so that everybody can stay on track. As an important aspect in experimental design of embodied learning and collaborative work, *Ethics and trusteeship* have been applied during this phase.	Students are given certain physics topic and a task to investigate through the means of mutual interaction and web. They build interest in certain domains of the topic.	Teacher determines a topic form school's curriculum, and then becomes a guidance through investigative process.	
	At the end of each scene, *Dialogue* between students who were performing and who were in the public. In this case, teacher can provide *Balance and navigation* through the dialogue, to assist the process of inquiry about scientific topic.	Students in the audience are starting to question and investigate scientific scene they witnessed, via mutual interaction and interaction with	If needed, teacher acts as guidance through the questioning of the students form the audience.	

	Interdisciplinarity is used to connect scientific theme and art based performance into questions, while exploring various *Possibilities* about phenomenon in question.	students who participated in science performance.		
Phase 2: **EVIDENCE:** students give priority to evidence	Students are participating in *Individual and collaborative activities*, where they explore many *Possibilities* that come from questioning. *Interdisciplinarity* comes from exploring representation of evidence through art. *Empowering* students is an important aspect and with *Risk, immersion and play* they can gain sense of ownership of the learning process. Teacher guides students through *Balance and navigation*.	Students are divided in groups based on their domain of interest. They gather and exchange information, while trying to organize and prioritize findings.	Teacher helps organize division of students in groups, and then acts as support. Teacher is here to help and guide through the process if necessary. The role of the teacher is also to answer concrete doubts that may occur during the gathering of information.	**Through the process of gathering evidence, students engage in presenting some of the examples they found through improvised acting and imagination of the scenery.**
	Interdisciplinarity is used to separate art from science in each scene, while students concentrate on *Possibilities* for the behavior of the scientific phenomenon.	Students in the audience use the performance as evidence.		

Phase 3: **ANALYSE:** students analyse evidence	Main feature is *Dialogue*, in which students with the teacher analyse evidence. During that process, every group is showing a form of stage representation of the evidence, backed up with analysis of the scientific phenomenon, and therefore engaging in *Interdisciplinarity.*	Still divided in groups, students engage in active discussions, trying to come up with suitable explanation and example of scientific phenomena, regarding Physics, Mathematics, Chemistry and Biology, from school curriculum. They use the teacher to reflect their ideas and get some guidance.	Teacher is here for support and guidance. Every group relates their ideas to the teacher, who guides them through inquiry (mostly with everyday examples included in inquiry) towards the path of explanation.	**Improvised acting is used to describe ideas and examples about different behaviors of the scientific topic, with vague and improvised ideas about the scenery and costumes.**
	Students in the audience use *Dialogue* to analyse evidence from the performance.	Students are participating in discussion, in groups, then publicly with teacher and students who	If needed, teacher acts as guidance through this process.	**Students from the public use improvised acting as a tool to analyse scientific phenomenon and**

		performed. They also use teacher to reflect their ideas.		**reflect their ideas on the teacher.**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students are *Playing* with many *Possibilities* for the representation of the knowledge they gained. *Interdisciplinarity* is achieved by using body movement to describe scientific phenomenon used for the topic. Through *Collaborative activities and Dialog*, students decide on the best embodied representation of scientific phenomenon.	With all the information explained, groups of students are working of best examples of behavior of scientific topic they are assigned to. After presentation from other groups, they are working on various possibilities for connecting different parts of scientific topic in new scenes, purpose being the better explanation of principals that lay	Teacher acts as guidance. Its role is point out possible errors, possible misunderstanding of the examples and possible difficulties in realizing that part of the performance.	**Students work on their representation of the subject. They perform their ideas to other groups, and every group participates by adding new concepts and discussing about good/bad perspectives of performance. Creativity and imagination are a crucial part of this stage.**

		behind.		
	Dialogue between students from the performance and the public is used to formulate the correct explanation of the observed scientific phenomenon. *Debate* can be used amongst students in the audience to clarify the explanations they created during previous CREATIONS phases.	Students who performed are helping the students from the audience to come up with correct explanation and also guiding them toward the correct answers to their previous questions and the correct explanation	Teachers acts as guidance. Teacher is also alert for the possibility of argument occurring during this phase of dialogue and debate.	

Phase 5: **CONNECT:** students connect explanations to scientific knowledge	In this phase, the main feature is *Interdisciplinarity*, because students connect their explanations of the scientific phenomenon with everyday life, though history, and through art-based performance. *Dialog* with the teacher speeds up this connection, because teacher *Navigates* them through everyday life occurrences of the phenomenon towards deeper understanding.	Students begin discussion about all segments of the scientific topic, connecting them with everyday events, and searching for more applications of principals they've discovered. Visit to the *research center* helps them to further understand how scientific phenomenon affects everyday life through history and interactive examples. Students engage in final preparation of the performance, in which they in groups form detailed script	Teacher could remind them about materials from different lessons and subjects, and if necessary motivate further discussion. Visit to the *research center* – teacher guides students to forming a conclusion and better connection of knowledge and principles that occur in everyday life.	**At this stage, every segment of the scientific topic in the performance is brought to life – each scientific phenomenon is played by one student – it can be seen, it can talk, and at some point, describe itself to the public.** **Presenting of the scenes,** **Forming final script and scenery.**

		for their part of the play, scenery and costumes. After presenting to the other groups, and after gathering advices from other groups, each scene is completely formed.	During the performing of each scene, teacher and art consultant make observation and maybe add a detail of their own to the play (informal, and in form of a suggestion). They help in ordering the scenes.	

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	For students in the audience, this phase is very similar - the main feature is *Interdisciplinarity*, because students connect their explanations of the scientific phenomenon with everyday life, though history, and through art-based performance. *Dialog* with the teacher speeds up this connection, because teacher *Navigates* them through everyday life occurrences of the phenomenon towards deeper understanding.	If possible, students who are in the audience have also visited the *research center/interactive exhibition/science,* but in their case, they discuss the scientific phenomenon they witnessed after this visit (this is not crucial, and in most cases not applicable, because public can be constructed of students from different schools)	Teacher could remind them about materials from different lessons and subjects, and if necessary motivate further discussion.	
Phase 6: **COMMUNICATE:** students	*Individual, Collaborative and Community based activities* in form of rehearsal and Main science - based art performance. *Interdisciplinarity* is also the key feature - now students are communicating physics through acting, to fellow students and to the wide audience.	Students are performing their findings in the form of the rehearsals, and are gathering needed materials and clothes for the	Encourages the students. Arranges final rehearsal at the venue and	**Numerous rehearsals and preparing materials for performance.** **Main performance**

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communicate and justify explanation	Such communication is part of an *Ethical* approach to science education engagement.	premiere performance. Students are engaged in the main event – art-based scientific performance	coordinates the final performance.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual and Collaborative reflective activities* – *Dialog* with assessment of the project, IBSE and embodied learning of science topic from school curriculum. *this phase is the same for both groups of students	Internal evaluation on the performance via mutual discussions about general event and each role. Discussion with the teacher.	At this point teacher takes part in internal evaluation and reflects on participation and engagement of each student.	

6. Additional Information

PEER FORCE should construct of one or more scientific topics which are clearly separated into different scenes. After each scene students from the audience are working on the explanation of the presented scientific concept. The number of the scenes is not previously defined, it depends on the arrangement between teacher and students.

It is recommended to have more than one main performance, if possible in another school, science centre/club or other convenient place. In this case, participants should consider the promotion of the event in school(s) and local media.

PEER FORCE concept is similar to Learning Science Through Theater(LSST), with additional values and activities that enrich concept of Science Play with peer learning and audience interaction.

- Useful information, guides to implementing creativity in science teaching and various communities: http://portal.opendiscoveryspace.eu/en/community/creations-842385
- CREATIONS Serbia community: http://portal.opendiscoveryspace.eu/el/community/creations-srbija-848766
- LSST demonstrator: http://creations-project.eu/wpcontent/uploads/2016/12/D3.1.2_Demonstrators_LSTT_FINAL.docx
- LSST community: http://portal.opendiscoveryspace.eu/en/community/learning-science-through-theater-841279

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation

Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

8. Possible Extension

Project PEER FORCE and similar activities are applicable to all STEM sciences and more. Possible extension could be change of subject, age and number of participants.

This project was conducted locally, so the next step would be to spread the word and ideas nationally, and engage more schools and teachers.

Upgrade of the scientific story and the script is also one possible extension, with adding more examples, scientific principals and behaviours, as well as adding experiments.

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.90 SCIENCE ART SHOW – Concentrate on details

Project Reference:	H2020-SEAC-2014-1, 665917	**Author**: Jelena Mijatovic (CPN)
Code:	D 3.2.90	**Contributors:**
Version & Date:	v1.0 November 13th 2017.	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

SCIENCE ART SHOW Demonstrator is based on 3d modeling and is applicable to all sciences.

1.2 Type of Activity

Project consists of two types of activities:

- School based activity
- Science center based activity

1.3 Duration

- This demonstrator consists of 7 types of workshops – each 90 min. Depending on the teachers and the students, some workshops can be held more times, in order to achieve better understanding of the scientific subject and achieving better results
- Overall duration of the project can vary from 1 week up to 2 months, depending on the agreement between the teacher and the students, and depending on cooperation and agreement with the Science Center

1.4 Setting (formal / informal learning)

- Formal – workshops that take place in a classroom
- Informal – workshops that take place in a Science Center

1.5 Effective Learning Environment

- Simulations
- Art-based
- Dialogic Space / argumentation

- Visit to research centres (virtual/physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

The greatest challenge of this demonstrator is coordinating the workshop activities and the use of 3D printer with a science centre or a science institution (almost none of the schools have a 3D printer). This leads to a smaller challenge – proper coordination between institutions.

This kind of educational activities are not traditionally used in education and accepting them as a learning tool is a challenge both for teachers and for students.

School system in Serbia rarely allows this kind of approach in a science classroom, due to extensive curriculum and lack of time during school hours. This leaves almost no space for teachers to implement creative activities, so these kinds of projects have to be realized in teachers' and students' free time, while honouring their other obligations, and also within time schedule of a science institution. This also leads to a very challenging time management.

3D modelling (or three-dimensional modelling) is the process of developing a mathematical representation of any surface of an object (either inanimate or living) in three dimensions via specialized software (Hamza Contractor et al, / (IJCSIT) International Journal of Computer Science and Information Technologies, Vol. 3 (2), 2012,3648-3649). For some students, this process of converting shape into mathematical figures can be very challenging. Conquering the software for 3D modelling sometimes isn't easy, so it's better to prepare for this plausible challenge.

2.2 Added Value

SCIENCE ART SHOW creates opportunities for students to participate in modern and technically advanced activities. The importance in this lays in the fact that the traditional school curriculums evolve very slowly while technology evolves quite fast. Today's generations of students feel a great need to incorporate modern technologies in the process of learning, so the use of computers for 3D workshops and the use of a 3D printer further motivates them to participate in this kind of creative learning activities.

The final result of the project is a Science Art Show, open for public. It's consisted of 3D models and explanations of the models written by the students. These explanations are short *science promotion* texts in which students in plain language explain their work to a broader audience. This can create a sense of a greater importance for students and proudness of their work.

The demonstrator provides informal and creative learning environment. During project's workshops students learn how to conquer the challenge of proper representation of the scientific subject they were working on.

Learning from 3D modelling and creating 3D models is applicable to a wide spectrum of subjects, topics and sciences. With 3d models, students can concentrate on every little detail about a specific topic or an object, or just look and learn about the bigger picture. Some examples are 3D models of a cell (biology), Solar

system (astronomy), atoms and molecules (chemistry), different geometrical figures (mathematics), different scales and shapes of surfaces, on Earth, Moon, other planets (can connect geography with biology and astronomy) etc.

In a study published in Journal of Educational Computing Research, Andrej Šafhalter, Karin Bakracevic Vukman, Srečko Glodež were exploring the 'The Effect of 3D-Modeling Training on Students' Spatial Reasoning Relative to Gender and Grade'.

The aim of this research was to establish whether gender and age have an impact on spatial reasoning and its development through the use of 3D modeling. The study was conducted on a sample of 196 children from sixth to ninth grade, of whom 95 represented the experimental group and 101 the control group. The experimental group received 3D modeling training in SketchUp software. Spatial reasoning was controlled in the initial and final stages with a test comprising tasks that required mental manipulation of shapes or objects in images. It was found that 3D modeling does improve spatial reasoning, regardless of gender or age (Journal of Educational Computing Research, Volume: 54 issue: 3, page(s): 395-406, Andrej Šafhalter[1], Karin Bakracevic Vukman[2], Srečko Glodež[3]; [1]Anice Černejeve Makole Lower secondary school, Makole, Slovenia; [2]Deparment of Psychology, Faculty of Arts, University of Maribor, Slovenia; [3]Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia).

3D modelling and 3D printing are a step towards the future. The bring students closer to some technological improvements already planned for the future trips to Moon and Mars. There are many ideas for using 3D printers in space, such as 3D printing with proteins, which will allow astronauts to print food, or 3D printer that can print themselves, and then print a base, machines etc. Some other technological improvements are connected with medicine – like 3D printing of bones, cartilage or in the future of different kind of cells or even organs.

3. Learning Objectives

3.1 Domain specific objectives

Main objective of SCIENCE ART SHOW is to create opportunities for pupils to visualize, model and explain a scientific topic from school curriculum in a modern and fun way. With guidance from the teacher pupils will:

- Create 3D models, based on selected science theme form school curriculum
- Explore through workshops about certain topics (individual and group effort)
- Gain deeper knowledge about selected scientific theme while concentration on the details
- Finnish 3D modeling course
- Learn how to connect art and geometry by representing a scientific theme
- Present their work in public activities

3.2 General skills objectives

- Learning how to make a 3D model
- Engaging in interdisciplinarity: connecting science classroom with art

CREATIONS has received funding from the European Commission HORIZON2020 Programme

- Developing creative and critical skills
- Developing better cooperation and teamwork skills
- Improving communication and social skills (during workshops)
- Improving writing and explanation skills
- Developing scientific inquiry skills

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

Aims of SCIENCE ART SHOW are to:

- Create an art-based platform for teachers, which they can implement into their classes
- Encourage students to use modern technology and creativity in the process of learning
- Engage students in learning about science
- Encourage students to teach and to learn from each other
- Eliminate prejudices about gender inequality in using modern technology and 3D modeling

4.2 Student needs addressed

- SCIENCE ART SHOW allows students to learn in a *creative environment*, in a classroom as well as in a science institution
- Through the realization of the project they are using *modern technology* as a *new and creative learning tool*
- Students have *guidance from the teacher* at all times
- Students have *the opportunity to express their ideas* to the public
- By the end of the project, students gained *the capacity to communicate science* to their peers and the public

5. Learning Activities & Effective Learning Environments

Science topic: **applicable to all sciences** Relevance to national curriculum: **primary school / high school curriculum** Class information Year Group: Age range: **10-21** Sex: **both** Pupil Ability: **All pupils could participate**	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) • **Computer for 3D workshops** • **3D printer** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* • **Workshops take place in school and/or science institution** • **Art Show takes place in school then in a science institution (or vice versa)** *Health and Safety implications?* **None** *Technology?* **Computers/laptops for students (they can work alone or in pairs), 3D printer** **-This can be organized in coordination with the science center/institution** *Teacher support?* **Science teacher is there to explain scientific phenomena during the process, , to paticipate in the process of creation and to evalute the result. There is also a 3D modeling teacher for workshops.**
Prior pupil knowledge - Basic knowledge about science phenomena or none, depends on the teacher and agreement between teacher and students about realization of the project	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

Project SCIENCE ART SHOW can be realized through following stages:

Stage 1: *Students are familiarized with the concepts of 3D modeling, art and science, IBSE and SCIENCE ART SHOW. They've filled out pre-questionnaires for Creations evaluation. Teacher and students have an agreement about scientific topic from school curriculum*

Stage 2: *Students have researched about scientific subject. One of more workshops that help clarify the subject with the teacher. Group visit to research center/interactive exhibition/science museum, related to the scientific topic, which allows students to gain deeper (visual) understanding about explored scientific topic*

Stage 3: *3D modeling course in cooperation with the science center*

Stage 4: *Connecting 3D modeling with the scientific subject, and 3D workshops*

Stage 5: Creating the models

Stage 6: *Writing short (fun) and easy science text, explaining the model*

Stage 7: *Connecting everything into a Science Art show – exhibition, design of text, invitations, openning*

Stage 8: Final result – Science Art Show

Assessment	Differentiation	Key Concepts and Terminology
Evaluation is done trough informal students' feedback and via formal assessment made by teacher	*How can the activities be adapted to the needs of individual pupils?* **All activities are adapted to pupils needs and knowledge.**	**Science terminology:** 3D modeling, 3D printer, geometry, mathematics **Arts terminology:** modeling, design, art show, writing

	Activities of preparation are divided by student interest.	

Session Objectives:

To adequately create a 3D model of a science subject, student will have to take it apart to every single detail, and learn how is everything connected and what is it made of. This allows students to gain deeper understanding about the scientific subject from curriculum. They will be able to communicate and explain that topic to the public with the same or less prior knowledge.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	*Dialogue* between teacher and students, about the scientific topic assigned to them. Teacher provides *Balance and navigation* through the dialogue and the process of investigation, so that everybody can stay on track. As an important aspect in this phase, *Ethics and trusteeship* have been applied during this phase.	Students are given scientific topic and a task to investigate through the means of mutual interaction and web. They build interest in certain domains of the topic.	Teacher gives student a scientific topic, and guides them through the process of questioning – how to start investigation	

			about a scientific topic	
Phase 2: **EVIDENCE:** students give priority to evidence	Students are participating in *Individual and collaborative activities*, where they explore many *Possibilities* that come from questioning. *Interdisciplinarity* comes from exploring representation of evidence through art. *Empowering* students is an important aspect and with *Risk, immersion and play* they can gain sense of ownership of the learning process. Teacher guides students through *Balance and navigation*.	Students are divided in groups based on their domain of interest. They gather and exchange information, while trying to organize and prioritize findings.	Teacher helps organize division of students in groups, and then acts as support. Teacher is here to help and guide through the process if necessary. The role of the teacher is also to answer concrete doubts that may occur during the gathering of information.	**Graphs and illustrations,** **Priority piramid**
Phase 3: **ANALYSE:** students analyse evidence	Main feature is *Dialogue*, in which students with the teacher analyse evidence. During that process, every group is showing a form of stage representation of the evidence, backed up with analysis of the scientific topic, and therefore engaging in *Interdisciplinarity*.	Still divided in groups, students engage in active discussions, trying to come up with suitable explanation and example of	Teacher is here for support and guidance. Every group relates their ideas to the teacher, who guides them	**Illustrations used to describe ideas and examples about different behaviors of the scientific topic, with vague and improvised**

		scientific phenomena from school curriculum. They use the teacher to reflect their ideas and get some guidance.	through inquiry (mostly with everyday examples included in inquiry) towards the path of explanation.	**ideas about representation.**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students are *Playing* with many *Possibilities* for the representation of the knowledge they gained. *Interdisciplinarity* is achieved by using illustrations and descriptions of real life application in describe scientific subject used for the topic. Through *Collaborative activities and Dialog*, students decide on the best geometrical representation of scientific subject.	With all the information explained, groups of students are working on details of scientific topic they are assigned to. After presentation from other groups, they are working on various possibilities for adding more details to their models.	Teacher acts as guidance. Its role is point out possible errors, possible misunderstanding of the examples and possible difficulties in representation.	**Students work on their representation of the subject.** **They present their ideas to other groups by drawing on the boad (large paper), allowing other groups to participate in adding their opinion - including their opinion and ideas. They discuss about good/bad perspectives of models. Creativity**

				and imagination are a crucial part of this stage.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	In this phase, the main feature is *Interdisciplinarity*, because students connect their explanations of the scientific phenomenon with everyday life, though history, and through art-based performance. *Dialog* with the teacher speeds up this connection, because teacher *Navigates* them through everyday life occurrences of the phenomenon towards deeper understanding.	Students begin discussion about all segments of the scientific topic, connecting them with everyday events, and searching for more applications of principals they've discovered. Visit to the *research center* helps them to further understand in more detail scientific topic, its role in everyday life, and connect with	Teacher could remind them about materials from different lessons and subjects, and if necessary motivate further discussion. Visit to the *research center* – teacher guides students to forming a conclusion and better connection of knowledge from everyday life.	**Design and illustration – every model is brought to life.** **Presenting of the models, with explanations.**

		previously gained knowledge. Students are making the models of their scientific subject with the help of a 3D modeling expert After presenting to the other groups, and after gathering advices from other groups, each model idea is completely formed.	During the presentation of models, teacher and 3D expert make observation and maybe add a detail of their own to the idea (informal, and in form of a suggestion).	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	*Individual, Collaborative and Community based activities* in form of presenting each explanation to the class. *Interdisciplinarity* is also the key feature - now students are communicating science through writing, to fellow students and to the wide audience. Such communication is part of an *Ethical* approach to science education engagement.	Students are writing the explanations of their models. Divided in groups, students are participating in preparations of the Science Art Show – arranging the model, sending invites to	Encourages the students. Helps with final preparations at the venue and coordinates the students.	**Design of the explanations texts,** **Arrangement of models,** **Connecting musical background with the models**

		guests, choosing the background music, and the time frame of the Science Art Show.		
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual and Collaborative reflective activities* – *Dialog* with assessment of the project, IBSE and embodied learning of science topic from school curriculum.	Internal evaluation on the performance via mutual discussions about general event and each role. Discussion with the teacher and 3D modeling expert.	At this point teacher takes part in internal evaluation and reflects on participation and engagement of each student.	**Drawing, illustrations**

6. Additional Information

The number of models is not previously defined, it depends on the arrangement between teacher and students.

It is recommended to have more than one main Science Art SHow, if possible in another school, science centre/club or other convenient place. In this case, participants should consider the promotion of the event in school(s) and local media.

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation

Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

8. Possible Extension

Idea for creating more advanced Science Art Show is to have same/similar science topics, but from different school subject, and/or different age (e.g. students from primary school and from high school). This includes coordination between more teacher of different subject from same or different school and with a science institution.

This extension creates much bigger Science Art Show, with different or much more detailed representations of the same subject. This can help students (and the public) in seeing scientific subjects from a different angle.

9. References

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- Journal of Educational Computing Research, Volume: 54 issue: 3, page(s): 395-406, Andrej Šafhalter[1], Karin Bakracevic Vukman[2], Srečko Glodež[3]; [1]Anice Černejeve Makole Lower secondary school, Makole, Slovenia; [2]Deparment of Psychology, Faculty of Arts, University of Maribor, Slovenia; [3]Faculty of Natural Sciences and Mathematics, University of Maribor, Slovenia

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.91 Science fiction - STEAM motivation

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Milena Mladenović**
Code:	D 3.2.91.	**Contributors: Aleksandar Gjorgijev**
Version & Date:		**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

"Science fiction – STEAM motivation" project is applicable to natural sciences such as chemistry, physics, electronics, engineering, but depending on individual products during project phases, any science can be represented

1.2 Type of Activity

Educational Activities based on Creativity- enriched Inquiry Based Approaches (**school based**).

It is can be local, national or international activity.

1.3 Duration

The project is conducted through four stages, where each one has a certain number of sub phases.

Introduction phase: around 90 min - two school classes in 6 days period (45min + 45min)

Next phase: up to 7 days
Students are creating proper settings for the problem and its solutions

Some phases students can realize in their homes – phase of reading literature, phase of developing pictures of future visions, developing movie scenarios…

Creating scenarios: 6 days

Preparation phase for film shooting: around 90 min – two school classes in 6 days period (45min + 45 min)

Film shooting (and framing): depending of the script, this can vary from 5 to 15 days.

Post-production phase: up to 7 days

Reflection phase: around 90 min – two school classes

Overall duration of the project can vary from 1 to 2 months, depending on students' work and objective work and life circumstances.

1.4 Setting (formal / informal learning)

Settings of the activities is formal.

Formal activities were performed in the school in language classes, art classes, computer classes, after class activities.

The demonstrator is designed to be applicable to all the needs and wishes of the teachers and students, so with the few modifications it can have formal and informal activities, e.g. if the shooting of the movie takes part outside of school, or there can be institutional cooperation, and it all depends on the age of the students, project's needs, teachers etc.

1.5 Effective Learning Environment

- Simulations
- Arts-based
- Dialogic Space / argumentation
- Experimentation in safe learning environment
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

School programme doesn't allow much time and space for informal learning of science disciplines/contents that are outside official school curriculum.

Target participants for the realization of this project are elementary school students, and also groups of older students - middle school and high school, whose work is based on school curriculum. Depending on this, challenges during the realization process can vary.

Challenge lays also in groups of younger students – low levels of knowledge and understanding of the scientific principles, as well as smaller science fiction domain appropriate and adjusted for younger age. This can be tricky especially in the argumentation phase of the project. This phase expects students to connect their scientific predictions in created scenario with scientific discoveries present today.

In groups of younger students, they will have to rely on teachers' guidance and assistance during realization of science experiments, which will create visual effects during film shooting. This can also be the case during post-production phase of movie montage, due to lack od knowledge in this area. All of this lead to a condition that teacher realizing the project must know how to use some of the programs for editing and montage of video materials.

For the older groups of students challenge may lie in the fact that this project is supposed to be interdisciplinary, meaning more teachers from different areas can be included in the project, but that entails their additional preparation and engagement, something for what some of the teachers are not prepared for.

2.2 Added Value

This project allows opportunities for developing interest to few STEM fields or individual science problems. Depending on the script that students develop for the movie, and also with which science problems and science fields will they deal with during the project.

This wide diazepam of topics which students can process during the realization of the projects gives possibilities to every individual student to focus their interests on specific science field or a topic, which can later guide them to a certain carrier choice.

Possibility to learn about the process of creation of the movie story and the freedom to be creative given to them by the field of science fiction, can guide some students towards creating science fiction contents in the future, which can ask new questions and open new challenges.

Aside from this, added value also lies in the following:

- Students are dealing with science from the future perspective – with prediction, which has a goal to motivate students to realize their predictions in the future.
- Students are dealing with ethics in science, analysing the consequences of technology development
- Students are dealing with sustainable development form the domain of science and technology
- Students are dealing with science from the perspective of movie scenes and effects (chemistry, electronics, engineering, physics…)

Their creative engagement students are exploring through the creation of literal work – script for the movie, drama elements – acting, they are learning about directing and framing the scenes, learning about scenography and photography.

3. Learning Objectives

3.1 Domain specific objectives

The aim of this project is to motivate students to continue working with STEM problems from different science fields, but also, movie alone can help promote STEM classes to a wider audience.

Another objective of this project is to give students a chance to express their visions of future using theatrical play and to push them further in to becoming a part of positive change by using science – as motivators, as well as future scientists.

With guidance from the teacher pupils will:

- Research terms necessary for describing scientific problems that they will represent in the movie
- Explore through tasks about certain topics (individual and group effort)
- Conduct scientific experiments that will enrich theatrical play
- Experience the process of creating a theater-like performance, writing a script, preparing the costumes, scenography, behaving on the stage and understanding a process of making movies
- Experience the process of being taught and evaluated by students
- Bring school closer to local community

3.2 General skills objectives

- Engaging in interdisciplinary: connecting STEM classroom with art
- Developing creative and critical skills
- Developing better cooperation and teamwork skills
- Improving communication skills
- Developing independence during research
- Developing competence in representation of gained knowledge
- Empowering students in public performance

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of this demonstrator is to show how creating a science fiction movie can have multiple benefits in the learning process. In perspective, it can build student's attitude towards ongoing scientific and civilizational challenges, like over-usage of planet's resources, exploration of space or interpretation of certain natural phenomenon. It then questions students' affiliations towards certain field of science (chemistry, physics, biology, ecology, engineering) and deepens their knowledge and interests in that direction. Then it connects all scientific knowledge into art form through the creation of the movie script,

creation of the scenography and effects (which partially rely on science experiments) and creation of a movie while becoming familiar with public performance, photography and framing.

Project is conceived for students ages 10-18 years. Although during project realization it is possible for a lot of teachers to be included, it is advised for only two teachers to be responsible for the project realization – one teacher from the arts field (literature or fine arts) and the other from natural sciences or engineering and informatics.

4.2 Student needs addressed

It was shown that students have more motivation during the learning process when they get the chance to explore their interests through the process of creation. In this specific case of creating a science fiction movie, students are incorporating their scientific knowledge with imagination and innovation and with theoretical background bordering fantasy. In this manner they are freeing their scientific potential, deepening their interests linked to a certain scientific field, questioning their curiosity which is the base of a well-motivated scientist.

5. Learning Activities & Effective Learning Environments

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: **Physics, Informatics, Chemistry, Biology…** Relevance to national curriculum: **Physics, Informatics, Chemistry, Biology, Literacy and Art curriculum.** Class information Year Group: **Primary school from 4th to 8th grade, Secondary school from 1st till 3rd grade** Age range: **10 -18** Sex: **both** Pupil Ability: **There are many activities and roles in this demonstrator, so various students can participate in various activities having in mind their abilities.**	Materials and Resources *What do you need? (eg.* printed questionnaires, teleconference, etc.) • **Short movie on subject of sci-fi predictions** • **Printed or digital card game** • **Material for drawing pictures** • **Laboratory equipment (Physics, Chemistry, Biology, Physics), or kitchen equipment, as well as home tools** • **Costumes** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Learning will take place in several spaces. Preparation will take place in school premises. Movie making, scene shooting will take place in places that students think are most suitable. Post-production phase will take place in school media (IT) classroom.** *Health and Safety implications?* **All science experiments conducted by students must be conducted with the presence and supervision of a teacher, to ensure that the risk of injuries can be avoided.** *Technology?* • **Projector** • **Camera (mini camcorder or mobile phone camera)** • **Computers with internet access** *Teacher support?*

	Teacher is there to introduce impact of sf movies on development of science, to steer a debate on important ethical issues in science, to guide students trough process of discovering solutions for science problem of their choice. Important teacher support role is also in helping students to conduct experiments and to synthetize knowledge they have gained from science and film making in to final product – sf movie. In younger groups of students teacher is the one that is doing post-production phase.

Prior pupil knowledge

- **Basic knowledge about making video clips using mobile phone**
- **Internet research methodology**
- **Basic, role play script whitening**
- **Cardboard modeling**

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

Project can be realized through following stages:

1. ***Stage:*** Students will understand how science is used in science fiction contents, as well as how SF content can influence development of science.
2. ***Stage:*** Students recognizing and acknowledging scientific challenges of our time, discuss and criticize importance of future scientific discoveries.
3. ***Stage:*** Students explore and engage the science problem of their choice, find evidence, analyze it and explain it.
4. ***Stage:*** Students create a solution for the scientific challenge presented through SF scenario for the movie.
5. ***Stage:*** Students gain basic training in movie making and photography.
6. ***Stage:*** Student make special effect for movie using science knowledge and experiments.
7. ***Stage:*** Students preparing scenography, costumes and stage performance.
8. ***Stage:*** Student observe and learn post-productive process.
9. ***Stage:*** Promotion of movies.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Evaluation is done through informal students' feedback and via formal assessment of teacher. One other informal feedback will be gained from general public audience.	*How can the activities be adapted to the needs of individual pupils?* Project includes variety of activities, and many of them can be adopted for student's individual needs. We have science experiments, art expression trough script writing, acting, drawing, modeling, then we have video recording, directing and producing. With this number of activities **first level of adaptation** can be that students can find their interest in different science subjects (Physics, IT, Chemistry, Biology, Robotics…). **The second level of adaptation** can be for those who do not find much interest in practical science to find their interests in artistic expression trough idea development for scripts, drawing and modeling, acting, video recording, directing, costume and scenography making. **The third level of adaptation** would be that we can adapt single activities to individual abilities.	**Science terminology:** Physics, Chemistry, Biology, IT, robotics. **Arts terminology:** scenery, costumes, script, performance/acting, photography, shooting movie, production

Session Objectives: During this project students will get deeper understanding of specific scientific challenges that are ahead of us and will try to think about solving them by using fiction and science at the same time. In this proses they will acquire knowledge about how to address scientific problem by using IBSE methodology, and how to promote possible solution to wider audience.				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose a scientifically oriented question to investigate. Balance and navigation through dialogue are accomplished with pre-designed questions. Questions are aroused through dialogue between students' scientific knowledge and the scientific information gain from Science-fiction video. While individual activity leads to greater sense of empowerment and agency, collaborative activities create trusteeship among group.	Students watch specific video with SF content that teacher prepared. Students play association based card game. Students are given to choose one from three given scientific	Will use challenging questions and the web videos to attract the students' interest in scientific problems that are not jet solved or are neglected.	

		breakthrough that they would like to see first discovered (ethical debate). Students discuss about scientific problems that are jet to be solved, and are/could be presented in SF movies. Students chose one problem and transform it in to scientific question.		
Phase 2: **EVIDENCE:** students give priority to evidence	Students *individually* collect data from internet that describe chosen scientific problem. In other *collaborative activity* they gather data and make presentation of evidence. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students are divided in groups based on their domain of interest. They gather and exchange information, while	Teacher helps organize division of students in groups, and then acts as support. Teacher is here to help and guide through the process if necessary.	**Photos, graphics, illustrations, video material.**

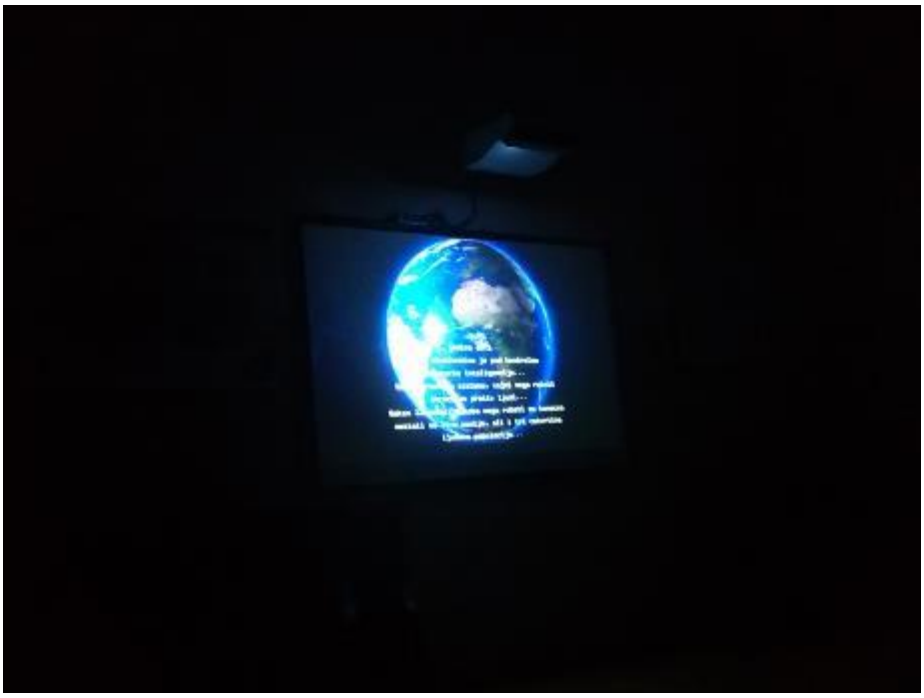
		trying to organize and prioritize findings.	The role of the teacher is also to answer concrete doubts that may occur during the gathering of information.	
Phase 3: **ANALYSE:** students analyse evidence	In *collaborative activity* Students analyze gathered information in groups that are formed, shaping gathered evidence into science-fiction prediction. Students analyze what part of question they have been answered with evidence they have gathered, and what part of question remained still unanswered - *Risk, immersion and play*	Students are using gathered data to explain idea behind the script they are developing, but in the same time present what part of question they will have to fill out with fiction part.	Teacher gives students form with pre-defined questions so they can easer categories and analyze gathered information.	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students are working on explaining scientific phenomenon or solving scientific problem using gathered data and implementing / transforming that data in to simulation/presentation - *Risk, immersion and play, Collaborative and individual activities.*	Students are making simulation of scientific solution for chosen problem. After each simulation presented to rest of the group there will be a discussion with questions.	Teacher acts as guidance. Its role is point out possible misunderstanding of the interpretation of presented	**Simulation can be experiment, but can be artistic model, or graphic.**

			scientific evidence. Teacher shows them other relevant researches.	
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	In this phase, the main feature is *Interdisciplinary*, because students connect their explanations of the scientific phenomenon with vision of solution for defined scientific problem/challenge. They will combine gathered evidence, personal theories and fiction so they can shape a story for a movie script.	Students are implementing gathered data (evidence and theories) in to movie script in which they have to explain how they have solved scientific problem.	.	**literary work, movie script**
	The *Interdisciplinary* comes out from the transforming movie script in to movie. Students need to understand how to emphasize relevant findings, theories and solutions in the form of movie.	Participate in theoretical and practical short course for movie making.	Teacher organize course for movie making.	**Photograhy**

	In to the process of shooting a movie, students and teachers will have to combine their scientific knowledge and use it for creating a scenography and special effects - *Risk, immersion and play*	Students will conduct the research and experiments to obtain visual effects for their movie. Students are shooting movie scenes.	Teacher will observe, monitor and give support in making visual effects for the movie using scientific knowledge.	**Movie making**
	Students and/or teacher are share their knowledge about applications for movie making in the post-production process.	Student are editing movie.	Teacher is giving the support in the movie editing process. The support can differ depending on students age.	
Phase 6:	Students communicate with the audience with their vision of a future, presenting their solution for defined scientific problem or challenge. They justify their idea through dialogue with other students or science educators, and with professional scientists.	Students answer questions, give additional explanation	Teacher facilitates discussion that	**Movie presentation**

COMMUNICATE: students communicate and justify explanation	In that way they can test their theories and their new way of thinking.	about idea and process.	will emerge after movie presentation.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Empowerment and agency* Individual and group analysis of acquired content. Suggestions for improvement of activities, realization and presentations	Discussion between students.	Guidance and support Dialog with students Dialog with public of the event	

6. Additional Information




ЈЕЗЕРА И БАРЕ
ШУМЕ

7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation

Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

8. Possible Extension

Future development according to the subject and potentials of project could be organization of local, national or international *film and short SF story festival*. The aim of this activity can be sharing experiences and ideas, as well as *opening debate* on responsible research and science ideas development path. Film festival can be with competitive character or just promotional character.

Students could make a step-by-step guide -*Student handbook*- on how they made the movie, so other students and teachers could easily jump into the movie-making.

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D3.2.92 SCIENCE PANTOMIME

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author**: Sanja Bulat (Primary school "Branislav Nusic")
Code:	D 3.2.92.	**Contributors:**
Version & Date:	v1.0 August 17th 2017.	**Approved by:NKUA**

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Mathematics, Chemistry, Biology, Geography… applicable to all natural sciences

1.2 Type of Activity

Educational activity based on creativity – enriches Inquiry Based Approaches, school based. Activity allows students to acquire knowledge in the field of natural sciences through pantomime performance

1.3 Duration

Overall duration: 2 months

- 5 weeks activities in school – 2nd week is planned for research, and 7th for event marketing

1.4 Setting (formal / informal learning)

Formal – activities and preparation are done in a classroom

1.5 Effective Learning Environment

- Communities of practice
- Dialogic Space / argumentation
- Art-based
- Experimentation (Science laboratories and eScience applications)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

School program doesn't allow much time for informal learning science topics or other science contents that aren't a part of a curriculum provided by the Ministry of education.

Students are burdened with a large number of obligations, so finding their free time for realizing this kind of activity poses a challenge.

Another challenge for student was finding a right way to connect science with the art of movement, because natural sciences a re rarely connected with art in that way.

2.2 Added Value

This kind of approach allows students to perceive topics from natural sciences from different angles. Through acting and humor students are:

- More motivated to gain knowledge
- Students are encouraged for a large personal engagement during the learning process
- Knowledge gained in informal ways is more likely to be applicable and long lasting

This king of activities also brings:

- IBSE learning, which is not used in school program in a sufficient percentage
- Student encouragement to defend their attitude with argumentation and to respect their interlocutor
- New visual association and movement, symbols that will help students in the continuing learning process
- Ability for students with special need which are working with inclusive curriculum to acquire more easily science knowledge that was presented and to be a part of these activities
- More strength in students to present their knowledge in public

And finally, moving away from written and oral ways of presenting topics from school curriculum and liberating students to try a new creative way was slowing activity flow, but it was overcome with carefully planned creative activities.

Science pantomime is conducted like regular pantomime, but with science, and not movies, tv shows, cartoons, books etc. Like in regular pantomime, when student start to explain their term, they first have to show a sign which represents is it a topic, definition, unit, physical quantity etc. The signs are agreed in the begging of the project between students and teachers.

Working on this project allows students and teachers to verify the level of their knowledge. It takes understanding of the science topic for them to properly show and explain something to their peers. Also, it

was shown that negative points for explaining the wrong kind of term motivated students to participate more seriously, and to re-examine learned knowledge.

Science topics presented by a specific movement can create different associations which will in students' knowledge system connect new contents more permanently and more applicable.

Activities in this project can be used for qualification of students knowledge, and can be graded, via sum total or a formal grade.

3. Learning Objectives

3.1 Domain specific objectives

Students are familiar with basics of a science topic they are learning through these activities, and a goal is to look and recognize topic, its properties and values in real life.

With guidance from the teacher, students will:

- Research and enumerate terms necessary for describing basic parts of natural science topic processed by these activities, going more and more in details during activities
- Define and select proper ways to represent these terms through pantomime
- Analyze their everyday surroundings and connect with the science topic
- Explore movement ideas for representation
- Empower their capability for representation
- Learn about different possibilities and different points of view
- Practice their marketing capabilities during the promotion of the event

3.2 General skills objectives

- Empowering students in seeking different learning approaches
- Developing independence during research
- Developing competence in representation of gained knowledge
- Engaging in multidisciplinary approach in teaching
- Developing cooperative skills
- Empowering students in public performance

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4. Demonstrator characteristics and Needs of Students

3.3 Aim of the demonstrator

Primary aim of this demonstrator is to explain how SCIENCE PANTOMIME was prepared and realized, so that teachers and science communicators that are interested in similar activities can have some guidance through the process.

This demonstrator explains the pedagogical framework that SCIENCE PANTOMIME was based on, and steps toward implementation of embodied learning of natural sciences, through movement and public performance.

Primary aim of the demonstrator is to explain the methodology for the implementation of SCIENCE PANTOMIME, and to give schools the opportunity to engage in art-based science performance.

3.4 Student needs addressed

Through various student interview, teachers noticed their need for a change in methods in acquiring and defining knowledge from natural sciences curriculum. Through experience with other activities that form a bond between natural sciences and art, it was concluded that merging science and art is something that motivates students in engagement during the process of gaining knowledge, in the process of research, in analysing and presenting personal knowledge to others.

Through team work students have the opportunity to individually choose the way they wish to participate in realizing tasks given during the project. Also, student with difficulty during individual learning can be more motivated and successful in acquiring knowledge through peer learning.

Student with hyperactivity issues can, following tasks through activities, we more engaged and successful and carriers of science class – which is for them much more motivational.

5. Learning Activities & Effective Learning Environments

Science topic: **Physics** Relevance to national curriculum: natural sciences primary and secondary school curriculum Class information Year Group: 5th – 8th grade primary school, 1st – 4th grade secondary school Age range: 12- 15, 15 - 19 Sex: both Pupil Ability: All pupils could participate	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Printed pre and post questionaires, printed science terms** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Project is relized in school – classroom, schoolyard, summer classroom and in school hall** *Health and Safety implications?* **None** *Technology?* *Teacher support?* **Teacher is guiding students through the process of exploration during the classes, on out-of-school activities, via social networks and via email correspondance. Art teacher is guiving instructions regarding performance, shows various techniques which students can use, and provides useful online tutorials and links where students can find examples of good practices. During rehearsals both teachers are correcting and suggesting, and after each session they are encouraging and directing disscussion between students.**
Prior pupil knowledge - Basic knowledge about science phenomena	

Individual session objectives (What do you want pupils to know and understand by the end of the lesson?)

SCIENCE PANTOMIME can be realized through couple of workshops with different activities.

Workshop 1: *Students are familiarizing themselves with the concept of pantomimical learning*

1st activity – Determing a number of science term from school curriculum, all connected to one subject
2nd activity – Students are divided in paires or groups, and are demonstrating each other how could a term be explained and shown
3rd activity – Defining terms which are most suitable for pantomimical representation

Workshop 2: *Students focus on body movement and empowering themselves for representation*

1st activity – Defining the rules for pantomimical realization (for ex. Sign for physics, sign for measurement unit etc.)
2nd activity – Acting education for students

Workshop 3: *Students are gaining more detailed knowledge about scientific topic*

1st activity – Students are divided in groups, they are choosing in interesting question within the scientific topic
2nd activity – By rotating student groups students are answering questions from other groups
3rd activity – Coming up with a way to represent given question and answer through pantomime

Workshop 4: *Students are becoming experts in visual representation with body movement*

Activity – Practicing techiques and pantomimical ways with mutural correction

Workshop 5: *Students gain ownership of the learning process by evaluting themselves before the final event*

Activity – In class, presenting each other and grading (students who are presenting and student with answers)

<u>Workshop 6:</u> *Students gain even more sence of ownership by organizing big event of science pantomime in their school*

Organization of activities in school during a particular school event, or as a separate event in schol hall (informing other students, parents etc.)

Assessment	Differentiation	Key Concepts and Terminology
Evaluation is done trough informal students' feedback and via formal assessment made by teacher	*How can the activities be adapted to the needs of individual pupils?* Students who show bigger interest for research will be leaders in that segment of activities, those who are more eloquent will be dealing with the organization, and those prone to public performance will demonstrate terms	**Science terminology:** ***natural sciences, research, exploring*** **Arts terminology:** ***scenery, costumes, script, body movement, performance***

Session Objectives: During this scenario, students will **deepen their understanding on scientific concepts and phenomena, using their creativity and imagination**				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Dialogue, Balance and navigation Through the storm of ideas, students and the teacher will define terms and topics from school curriculum. They are exploring with firm steps which of the topics or terms is more appealing for pantomimical representation. They select the topic for the activities.	Students are playing with words and terms form natural sciences. They write ideas on the board, discuss and choose a couple of appropriate topics.	Teacher guides students or suggests topics from school curriculum.	**During this word play, students also play with body movement and drawings.**
Phase 2: **EVIDENCE:** students give priority to evidence	Individual, collaborative and communal activities for change Based on a science topic, students are conducting a research, gathering all potential information.	Students are conducting research in groups, they singly determine who will do	Teacher is giving guidance for research – safe web addresses, encyclopedias, ideas for visit to	**Students express pantomimical ideas, and analize different**

		which task of research within the group	research facilities… Teacher also suggests possible ways for representation, guide activities of individuals and groups	**types of performance /appearance**
Phase 3: **ANALYSE:** students analyse evidence	Individual, collaborative and communal activities for change Students analyze gathered information, selecting certain information that they think is important for presentation.	Students decide on their own the way of selection and storing gathered information. They decide about with research institution/center to visit. Students decide do they want and to what level engagement of parents in realization of activities.	Teacher provides guidance and suggests different (web) tools and techniques for storing information.	**Watching and evaluating different performances, stand-ups, street artists**

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Possibilities Students are coming to a conclusion about their research and effects of the science topic to their surroundings. Students are thinking about ways to represent their assumptions about scientific phenomenon.	Students are connecting and applying gathered information	Teacher reminds students of examples about different scientific topic, conclusions and IBSE steps	**Imitation of different forms of acting and pantomime**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Balance and navigation Students analyze additional contents and consult with teacher to check if their conclusions are correct and in accordance with latest scientific achievements.	Students connect personal conclusions with scientific facts. They demonstrate results of their research through some sort of an experiment. Students present evidence for the results of their research – some other research, textbook… Students can connect with high school	Teacher reminds students about previously gained knowledge, as from that particular subject as from other subject in school. Teacher shows them other researches. Teacher can guide them to	

		students and have discussions with them – in person or online	some other experimental techniques and allows them means for realizing them.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Dialogue, Possibilities, Ethics and trusteeship Students are discussing within the group and with the teacher about ways of research and exploring, relevant sources of information (online safety), ways of most adequate representations… Students are discussing within the group and with art teacher – proper ways of representation of evidence with body movement. Groups discuss between them and add suggestions.	Students present information, make conclusions, make arguments, contradict non-consensual facts, analyze engagement of all participants, make suggestions for improvement od representations.	Teacher coordinates discussion, reminding everyone about the rules of debates	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	Empowerment and agency Individual and group analysis of acquired content. Suggestions for improvement of activities, realization and presentations	Discussion between students	Guidance and support Dialog with students	

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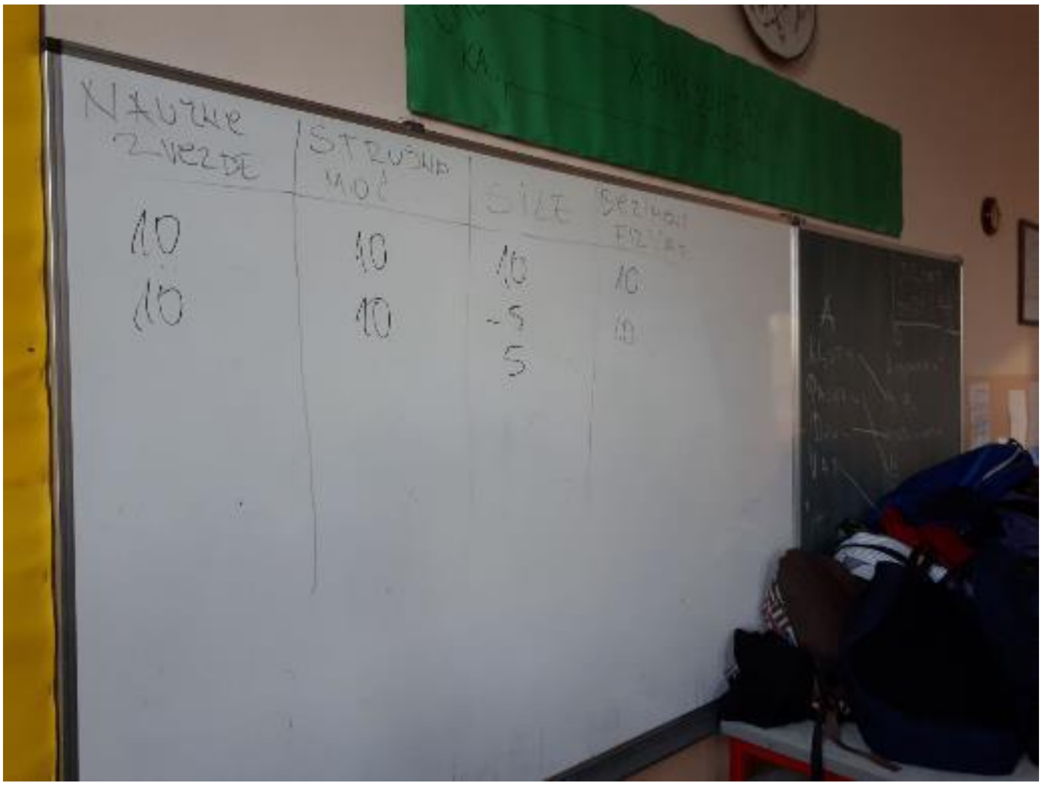
			Dialog with public of the event	

6. Additional Information


CREATIONS



7. Assessment

Assessment should be conducted via standardized Creations questionnaires for students' evaluation

Students fill out pre-questionnaires before starting the project, and post-questionnaires after the project end. Teacher fills out teachers' questionnaire at the end of the project.

8. Possible Extension

This project can be realized to be in a form of a school manifestation, or in a local level (municipality). That manifestation can be in a form of a competition, between classes and schools.

It would be good to ask for a support from the local community and media.

9. References

D3.2.93 TBVT show

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Javier Santaolalla Camino
Code:	D 3.2.93.	**Contributors:**	
Version & Date:	**V1 25/05/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, biology, chemistry, arts

1.2 Type of Activity

High school, secondary. Local level (Spain)

1.3 Duration

1 hour 30 min – session 1

1 hour 30 min – session 2

1.4 Setting (formal / informal learning)

Informal learning, this activity is designed to be performed in a theatre (session 1) and a room (session 2)

1.5 Effective Learning Environment

Arts-based
Dialogic space
Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

Students have a negative perception towards science: it is difficult, boring and only suitable for few. Our challenge is changing this perception showing the reality of science: how a scientist looks like, what is a scientist actually doing, what are the possibilities of working in science. And at the same time making it entertaining. In a second session students explain science in their own language.

2.2 Added Value

Students have the possibility of interacting with scientists through an open questions session after the performance. In this interaction discussion is open and questions like "how do you become a scientist", "what is your field of research" are always raised. For most of the students this is the first time they see a scientist, they interact with a scientist and they can actually ask a question to a scientist. Previous work during the performance is intended to break barriers with students and shorten the distance between audience and scientists.

3. Learning Objectives

3.1 Domain specific objectives

- Learn about specific topics in science: biology, physics, chemistry mainly.
- Relative to particle physics: learn how collisions are produced, what are the goals of a big accelerator, importance of density of energy in a collision.
- Show specific up to date researches in 4 fields of science.
- Learn about non-verbal language

3.2 General skills objectives

- Break stereotypes
- Demystify science and scientists
- Shorten distance between students and scientists
- Open a channel for dialogue students-scientists
- Women role in science
- Interdisciplinary: between science and arts, and between different fields in science
- Communication skills

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4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

To explain recent developments in science using scenic arts and the stand-up format, this way science is presented in a more attractive way to students. The final dialogue aims to create an open channel of discussion student-scientist. Students learn by IBSE model to explain science in their own way

4.2 Student needs addressed

- Learn science in a more attractive way
- Satisfy curiosity
- Role model, students see a real scientist
- Possibility to express their worries and questions about science career, scientists and also developments in science.
- Capacity to communicate science

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5. Learning Activities & Effective Learning Environments

Science topic: Science in general, particle physics in particular (Relevance to national curriculum) Class information Year Group: High School (3º 4º ESO and 1º 2º Bach) Age range: 14 - 18 Sex: both Pupil Ability: All inclusive	**Materials and Resources** *What do you need? Performance requirements : stage, micros, sound equipement, projection* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? Theatres and event halls* *Health and Safety implications? None* *Technology? Not necessary* *Teacher support? To control students in the room and accomodation*

Prior pupil knowledge
Not necessary

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***
During this scenario, students will learn about individual topics in science (mainly in particle physics, but also biology and chemistry), will have the chance to interact with scientists and will connect science with arts. In a second session they will apply what they learnt and explain a scientific topic with their own words.

Assessment **Interactions with students during and after the show. Use of Social Nets**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* The Q&A part can address individual needs	**Key Concepts and Terminology** **Science terminology:** **physics, chemistry, biology** **Arts terminology: Dramatization of science, performance**

Session Objectives: learning in a creative and attractive way, taking science out of the classroom
During this scenario, students will learn about science and interact with scientists.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION: students investigate a scientifically oriented question**	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students choose a scientific topic that he/she finds interesting. Some videos are displayed to inspire the decision	Teachers are provided with models of what the activity is intended to teach	**Scientific questions are distributed among the groups. Students must collaborate to explain the aswers in a**

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				dramatized manner. In groups students find similar scientific questions on their own
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students are oriented towards different source of information, trying to order the data as it answers different questions: how? When? What for? They start creating a story	Explaining a scientific topic in the form of a stand-up show is a challenge. Teachers must give orientation to help ordering the ideas	**Flowchart or conceptual map with the ideas coming from the previous investigation**
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	In groups students analyze the data and discuss a possible structure to guide the script to be played from the introduction to the conclusions following a story	At each step ideas are presented to the coordinator to give orientation and discard ideas that probably take to no-end situations.	

Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Using evidence students formulate the explanation. Final explanation has to be linked to the story they are creating	Teachers help discarding no scientific ideas	**Connected ideas are displayed in a map that takes from the initial question to the final answer**
Phase 5: **CONNECT: students connect explanations to scientific knowledge**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Scientific knowledge related to the topic is presented as input to each group. Groups have to find a way to connect their idea with the ideas given.	Motivate new ideas not presented to the group. Try to link the efforts of the different groups together	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Each group complete the story they have been creating during the session to be presented in front of other students in the form of a stand up show.	Orientation to complete the story in the classic form: introduction – content – conclusion.	**The activity itself has a lot of art potential**
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	After the session (once all groups have presented their play) an Q&A session is open	Teachers guide the Q&A phase so that the whole process (7 phases) is clear	

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6. Additional Information

N/A

7. Assessment

Students and teachers will evaluate the demonstrator using questionnaires (independent for teachers and students)

8. Possible Extension

The stand-up script produced by students on a science topic can be played with us. It would be an interesting possibility since students could serve as an element to even shorten distance between the performers (scientists) and the audience (students)

9. References

D3.2.94 Science monologue national contest

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Javier Santaolalla Camino**	
Code:	D 3.2.94.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1Introduction / Demonstrator Identity

1.1 Subject Domain

Science plus arts. The science topic developed depends on the student interests, and includes all fields considered in the STEM acronyms. Arts is included in the own nature of the activity

1.2 Type of Activity

School based activity, where the teacher guides the student to develop the text to be presented.

1.3 Duration

4 months

1.4 Setting (formal / informal learning)

It is a school based activity. Teacher can work individually or in groups to prepare the scripts.

1.5 Effective Learning Environment

Communities of practice

Art-based

Dialoguic space/argumentation

Communication of scientific ideas to audience

2 Rational of the Activity / Educational Approach

2.1 Challenge

- *Motivate the student towards science. By allowing the student choose the topic he is going to work feeling he is in control of his own learning process (agency)*
- *Improve communication skills of students. In traditional teaching there is not much space to improve communication skills, since most of it implies passive learning. In this activity the student goes in the stage and communicate the science he has learnt.*
- *Communication of ideas to the public. The student learns and apply different techniques to share his content to the audience, the general public.*

2.2 Added Value

This demonstrator is linked to other demonstrators created by The Big Van Theory. The original idea is using scenic arts to improve communication in science. In this case it is the student who takes the lead of the activity and becomes an actor.

The whole process involved in the activity includes all the elements of CREATIONS pedagogical framework: first the student choose a topic in science (agency), then the teacher works with the students in this topic (communication, navigation, dialogue…), the student learn the scientific content related to this topic, the student creates a script based on what he has learnt, the student creates a video performing his script and distributes/shares this video in social media to get "points" (communication to general public), the students perform in front of the audience (arts).

The Big Van Theory will create all material so that students and teachers are guided in all the steps of the process.

3 Learning Objectives

3.1 Domain specific objectives

Communication of science through stand-up shows using humor as a vehicle for learning has been shown to be useful to motivate and engage students.

Domain objectives and general objectives, in this case, are the same, since students work with the topic of their preference.

The main objectives of this activity are:

- Increase agency of student in science learning process
- Critical thinking by analysis of scientific information
- Dialogue: working in groups to prepare the script. They share ideas and communicate what they learn
- Breaking stereotypes: science is boring and science is difficult, both statements are challenged by this activity where students have fun making others laugh with a science based script.
- Communication skills, arts. They go in stage and communicate science. They have to use different skills usually developed in the scenic arts.
- Connect and share with audience. Since audience is part of the jury of the contest, students have to reach as many people as possible, making them aware of the importance of high impact in communication of science.

3.2 General skills objectives

Since this activity is not focused in any particular field of science, general and specific objectives are the same.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to give teachers a tool to increase motivation of students in science. Being a national contest for students and teachers motivation not only comes by the fact that students has the possibility to choose the topic they work with, but also the prize of the contest, being a trip to Bilbao to take part of the biggest science show in Spain, and the special prize of a trip to CERN were an art at CMS activity can be developed for this occasion.

4.2 Student needs addressed

The main need addressed is communication skills. Students usually finish their professional preparation with few or no experience in communication. Whereas communication is a crucial part of everyday work and life, education usually disregards this part of the learning process. In this activity students work their favourite science topic and they create their own script and they perform it in front of other students, who, at the same time, learn from the work of their schoolmates.

5 Learning Activities & Effective Learning Environments

Science topic: not specific (Relevance to national curriculum) Class information Year Group: secondary (3 ESO to 2 Bachillerato) Age range: 14-18 Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? Students need a camara to record their performance, internet connection to upload it to internet. For the final, a theater.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? It is an online contest where the final event takes place in a theatre* *Health and Safety implications? Those of the theatre* *Technology? Internet connection* *Teacher support? It is not required but suggested.*
Prior pupil knowledge **Not required**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will learn about different science topics, communication skills, how to share and increase the impact of your content.		
Assessment **Questionnaires will be available before and after the sessions**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Since work can be both individual and in groups, it is easily adapted to their individual needs	**Key Concepts and Terminology** **Science terminology: any related to STEM careers** **Arts terminology: dramatization of science**
Session Objectives: During this scenario, students will have the ability to go in front of a group of people and explain better their knowledge.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students can use material offered by TBVT to find their preferred topic.	Teachers are given material to open questions that can motivate curiosity of students	**Videos and monologues can be part of the material**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students search in books and on internet to get a better knowledge of their chosen topic.	Teachers offer information and complete the students knowledge of the chosen topic	**Videos and monologues will be available**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	In groups or individually they work in the evidences to create a script	Teacher supervise the work in gruops	**This is part of the preparation of the script so arts are included in the own nature of the activity**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.Students create a script where they explain what they have learnt in a funny way	Teachers complement the work of the students	**Since it is a dramatization, arts are part of this activity in this point**
Phase 5:	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both	In the whole process of creation of the script	. Teacher is guiding the	**The dramatization of the science topic is the**

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CONNECT: students connect explanations to scientific knowledge	disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	they have to connect different ideas	process to connect ideas	**artistic part of this step**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students perform in front of other students	Teacher guide the dialogue after the performance	**It is a performing activity**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Q&A follow the show, and this part is used to reflect about the whole process	Teacher guide the Q&A part	**It is again a performing based activity**

6 Additional Information

This is the third edition of this national contest. In previous years 10 thousand students were reached with this activity, more than 300 teachers were empowered to lead the students in the process and some 200 monologues were presented to the contest.

This national contest is organized in collaboration with NAUKAS (http://naukas.com/), the Catedra de Cultura Científica de la Universidad del País Vasco and TBVT.

Previous edition of this contest are available here:

http://www.fundaciontelefonica.com/educacion_innovacion/formacion-ciencia-stem/

7 Assessment

Questionnaires will be used to test the activity.

8 Possible Extension

This contest could be applied in an international level

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9 References

D3.2.95 Science on stage Workshop for Teachers

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Javier Santaolalla Camino**	
Code:	D 3.2.95.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Teachers learn how to communicate science on stage.

In the workshop teachers learn how to create a script to be performed on stage. Teachers prepare the script on their own. Finally all scripts are presented in the classroom.

1.2 Type of Activity

School based activity

1.3 Duration

3 hours

1.4 Setting (formal / informal learning)

It is a school based activity

1.5 Effective Learning Environment

Communities of practice

Art-based

Dialoguic space/argumentation

Communication of scientific ideas to audience

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2 Rational of the Activity / Educational Approach

2.1 Challenge

- *Motivate teachers to innovate in education of science*
- *Improve communication skills of teachers.*
- *Motivate teachers to include oral presentation of students in the classroom*

2.2 Added Value

Besides the knowledge the teachers will acquire during the preparation of thier topic and the presentations of the other students, they learn communication.

3 Learning Objectives

3.1 Domain specific objectives

The main domain objectives of this activity are:

- Dialogue: working in groups to prepare the script. They share ideas and communicate what they learn
- Communication skills, arts

3.2 General skills objectives

Since the activity is open in the topic the teachers choose, its general objectives are the same as the domain ones.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to give teachers a tool to increase motivation of students by introducing innovative techniques of teaching. They can transform their traditional oral lectures into a perform. In addition they can motivate students to do so, including in their curriculum presentations and oral lectures by students. Finally, students can participate in both Ciencia Show and Ciencia Clip. This demonstrator capacitate teachers to help students to create both a monologue and a Youtube video to participate in the contests.

4.2 Student needs addressed

The main need addressed is communication skills of teachers. Teachers usually don't innovate in their classrooms. A lot of techniques from scenical arts can be applied to the classroom as well as narrative, storytelling. These skills can shorten the distance between students and teachers.

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5 Learning Activities & Effective Learning Environments

Science topic: general (Relevance to national curriculum) Class information Year Group: teachers Age range: none Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? A classroom for the workshop.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? A classroom* *Health and Safety implications? None* *Technology? none* *Teacher support? None*
Prior pupil knowledge **Not required**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* Communication skills	

Assessment	Differentiation	Key Concepts and Terminology
Questionnaires will be available after the sessions	*How can the activities be adapted to the needs of individual pupils?* Since work can be both individual and in groups, it is easily adapted to their individual needs	**Science terminology: any field of science** **Arts terminology: dramatization, performing arts**

Session Objectives:

Learn physics in a different way, show the impact of videos on todays learning process.

Learning activities in terms of CREATIONS Approach

IBSE Activity	Interaction with CREATIONs Features	Student	Teacher	Potential arts activity
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	Each student choose a topic and investigate about it	-	**Youtube Videos can help find a topic of**

	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			**their interest**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	In groups students have to find evidence to the proposed questions	-	**They find solutions to the questions by watching other videos**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the evidences and create a script with them	-	**This is part of the preparation of the script so arts are included in the own nature of the activity**

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students create a script where they explain what they have learnt in a funny way	-	**Since it is a dramatization, arts are part of this activity in this point**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	In the whole process of creation of the script they have to connect different ideas	-	**The dramatization of the science topic is the artistic part of this step**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students perform their script in front of other students	-	**It is a performing activity**
Phase 7:	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Q&A follow the presentations, and this part is used to reflect about the whole process	-	**It is again a performing based activity**

REFLECT: students reflect on the inquiry process and their learning				

6 Additional Information

N/A

7 Assessment

Questionnaires will be used to test the activity.

8 Possible Extension

Do it at international level.

9 References

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.96 Science on stage Workshop

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Javier Santaolalla Camino**
Code:	D 3.2.96.	**Contributors:**
Version & Date:		**Approved by:NKUA**

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Students learn how to communicate science on stage.

In the workshop students learn how to create a script to be performed on stage. Students prepare the script on their own with support from teachers. Finally all scripts are presented in a theatre.

1.2Type of Activity

School based activity

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

It is a school based activity

1.5Effective Learning Environment

Communities of practice

Art-based

Dialoguic space/argumentation

Communication of scientific ideas to audience

2 Rational of the Activity / Educational Approach

2.1 Challenge

- *Motivate the student towards science*
- *Improve communication skills of students. In traditional teaching there is not much space to improve communication skills, since most of it implies passive learning*
- *Communication of ideas to the public. The student learns and apply different techniques to share his content to the audience, the general public.*

2.2 Added Value

Besides the knowledge the students will acquire during the preparation of thier topic and the presentations of the other students, they learn communication skills and they have an experience to talk in public.

3 Learning Objectives

3.1 Domain specific objectives

The main domain objectives of this activity are:

- Increase agency of student in science learning process
- Critical thinking by analysis of scientific information
- Dialogue: working in groups to prepare the script. They share ideas and communicate what they learn
- Breaking stereotypes: science is boring and science is difficult, both statements are challenged by this activity where students have fun making others laugh with a science based script.
- Communication skills, arts

3.2 General skills objectives

Since the activity is open in the topic the student choose, its general objectives are the same as the domain ones.

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4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to give teachers a tool to increase motivation of students in science and prepare students to participate in the national contest Ciencia Show.

4.2 Student needs addressed

The main need addressed is communication skills. Students usually finish their professional preparation with few or no experience in communication. Whereas communication is a crucial part of everyday work and life, education usually disregards this part of the learning process. In this activity students work their favourite science topic and they create their own script to be performed on stage

5 Learning Activities & Effective Learning Environments

Science topic: general (Relevance to national curriculum) Class information Year Group: secondary (3 ESO to 2 Bachillerato) Age range: 14-18 Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? A classroom for the workshop. A theatre for the show.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? A classroom / a theatre* *Health and Safety implications? None* *Technology? none* *Teacher support? It is not required but suggested.*
Prior pupil knowledge **Not required**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* Communication skills	

Assessment	Differentiation	Key Concepts and Terminology
Questionnaires will be available before and after the sessions	*How can the activities be adapted to the needs of individual pupils?* Since work can be both individual and in groups, it is easily adapted to their individual needs	**Science terminology: any field of science** **Arts terminology: dramatization, performing arts**

Session Objectives:

Learn physics in a different way, show the impact of videos on todays learning process.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	Each student choose a topic and investigate about it	Teacher supervise this process	**Youtube Videos can help find a topic of**

	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			**their interest**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	In groups students have to find evidence to the proposed questions	Teacher will supervise the process	**They find solutions to the questions by watching other videos**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the evidences and create a script with them	Teacher supervise the work in gruops	**This is part of the preparation of the script so arts are included in the own nature of the activity**

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students create a script where they explain what they have learnt in a funny way	Teachers complement the work of the students	**Since it is a dramatization, arts are part of this activity in this point**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	In the whole process of creation of the script they have to connect different ideas	Teacher is guiding the process to connect ideas	**The dramatization of the science topic is the artistic part of this step**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students perform their script in front of other students	Teacher guide the dialogue after the performance	**It is a performing activity**

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Q&A follow the presentations, and this part is used to reflect about the whole process	Teacher guide the Q&A part	**It is again a performing based activity**

6 Additional Information

N/A

7 Assessment

Questionnaires will be used to test the activity.

8 Possible Extension

Do it at international level.

9 References

D3.2.97 Science on Youtube Workshop

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Javier Santaolalla Camino**
Code:	D 3.2.97.	**Contributors:**
Version & Date:		**Approved by:NKUA**

1 Introduction / Demonstrator Identity

1.1 Subject Domain

We explore the deepests secrets of nature through Youtube videos.

Youtube videos are used to introduce the lesson, which refers to the biggests mysteries in fundamental physics. After the videos the students in groups work together in orther to find possible answers to these mysteries. Finally they write a script for a video where the question plus the possible solution is presented.

1.2 Type of Activity

School based activity plus individual home based work.

1.3 Duration

2 hours

1.4 Setting (formal / informal learning)

It is a school based activity working on groups

1.5 Effective Learning Environment

Communities of practice

Art-based

Dialoguic space/argumentation

Communication of scientific ideas to audience

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2 Rational of the Activity / Educational Approach

2.1 Challenge

- *Motivate the student towards science, using Youtube as a channel to connect with students.*
- *Improve communication skills of students. In traditional teaching there is not much space to improve communication skills, since most of it implies passive learning*
- *Improve computing skills to communicate science*
- *Communication of ideas to the public. The student learns and apply different techniques to share his content to the audience, the general public.*
- *Learn about modern high energy physics*

2.2 Added Value

In this activity we use Youtube for two purposes: first we show its potential to start a topic of interest in the classroom, and to spark an interesting dialogue; then to motivate students to work in topics after school. This Demonstrators connects with the Youtube contest: Ciencia Clip.

Teachers can use these videos in order to introduce their lessons and grab their attention.

3 Learning Objectives

3.1 Domain specific objectives

Communication of science through videos is very useful to motivate and engage students. Youtube is the channel they mostly use to get information. Youtube is the "language" of new generations.

The main domain objectives of this activity are:

- Get in touch with modern physics: expansion of the Universe, matter-antimatter asymmetry, dark matter and unification theories.
- Learn about open questions in science: science is not a completed set of theories but something that is in constant evolution and review.

3.2 General skills objectives

- Increase agency of student in science learning process
- Critical thinking by analysis of scientific information
- Dialogue: working in groups to prepare the script. They share ideas and communicate what they learn
- Breaking stereotypes: science is boring and science is difficult, both statements are challenged by this activity where students have fun making others laugh with a science based script.
- Communication skills, arts. They prepare the script of a video.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to give teachers a tool to increase motivation of students in science and prepare students to participate in the international contest Ciencia Clip.

4.2 Student needs addressed

The main need addressed is communication skills. Students usually finish their professional preparation with few or no experience in communication. Whereas communication is a crucial part of everyday work and life, education usually disregards this part of the learning process. In this activity students work their favourite science topic and they create their own script to be recorded in front of the camara.

Secondary need is showing students modern physics that is actually beyond what they learn in school. Getting a taste of modern physics is an efficient tool to motivate students towards physics.

5 Learning Activities & Effective Learning Environments

Science topic: high energy physics (Relevance to national curriculum) Class information Year Group: secondary (1 to 2 Bachillerato) Age range: 16-18 Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? A projector and a big screen with sound system. Internet conection* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? A classroom* *Health and Safety implications? None* *Technology? Internet connection, projector and screen* *Teacher support? It is not required but suggested.*
Prior pupil knowledge **Not required**	
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* Science is an open field, what are the main mysteries in modern physics, importance of communication of ideas.	

Assessment **Questionnaires will be available before and after the sessions**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Since work can be both individual and in groups, it is easily adapted to their individual needs	**Key Concepts and Terminology** **Science terminology: high energy physics** **Arts terminology: audiovisual**

Session Objectives:

Learn physics in a different way, show the impact of videos on todays learning process.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional	After the videos presenting the questions under study, the students have to find possible answers to them (in groups)	Teacher can help the groups	**Youtube Videos will introduce**

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	scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.			**the questions**
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	In groups students have to find evidence to the proposed questions	Teacher will supervise the process	**They find solutions to the questions by watching other videos**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students analyse the evidences and create a script with them	Teacher supervise the work in gruops	**This is part of the preparation of the script so arts are included in the own nature of the activity**

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Students create a script where they explain what they have learnt in a funny way	Teachers complement the work of the students	**Since it is a dramatization, arts are part of this activity in this point**
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	In the whole process of creation of the script they have to connect different ideas	Teacher is guiding the process to connect ideas	**The dramatization of the science topic is the artistic part of this step**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students perform their script in front of other students	Teacher guide the dialogue after the performance	**It is a performing activity**

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Q&A follow the presentations, and this part is used to reflect about the whole process	Teacher guide the Q&A part	**It is again a performing based activity**

6 Additional Information

N/A

7 Assessment

Questionnaires will be used to test the activity.

8 Possible Extension

Include a workshop in acting and audiovisual arts.

9 References

D3.2.98 Science youtube video international contest

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Javier Santaolalla Camino**	
Code:	D 3.2.98.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1 Introduction / Demonstrator Identity

1.1 Subject Domain

Science plus arts. The science topic developed depends on the student interests, and includes all fields considered in the STEM acronyms. Arts is included in the own nature of the activity

1.2 Type of Activity

School based activity, where the teacher guides the student to develop the text to be presented.

1.3Duration

3 months

1.4 Setting (formal / informal learning)

It is a school based activity. Teacher can work individually or in groups to prepare the scripts and help produce the videos.

1.5Effective Learning Environment

Communities of practice

Art-based

Dialoguic space/argumentation

Communication of scientific ideas to audience

2 Rational of the Activity / Educational Approach

2.1 Challenge

- *Motivate the student towards science. By allowing the student choose the topic he is going to work feeling he is in control of his own learning process (agency)*
- *Improve communication skills of students. In traditional teaching there is not much space to improve communication skills, since most of it implies passive learning. In this activity the student goes in the stage and communicate the science he has learnt.*
- *Improve computing skills to communicate science*
- *Communication of ideas to the public. The student learns and apply different techniques to share his content to the audience, the general public.*

2.2 Added Value

This demonstrator is linked to other demonstrators created by The Big Van Theory. The original idea is using youtube videos to improve communication in science. In this case it is the student who takes the lead of the activity and becomes an actor.

The whole process involved in the activity includes all the elements of CREATIONS pedagogical framework: first the student choose a topic in science (agency), then the teacher works with the students in this topic (communication, navigation, dialogue…), the student learn the scientific content related to this topic, the student creates a script based on what he has learnt, the student creates a video performing his script and distributes/shares this video in social media to get "points" (communication to general public)

The Big Van Theory will create all material so that students and teachers are guided in all the steps of the process.

3 Learning Objectives

3.1 Domain specific objectives

Communication of science through videos is very useful to motivate and engage students. Youtube is the channel they mostly use to get information. Youtube is the "language" of new generations.

Domain objectives and general objectives, in this case, are the same, since students work with the topic of their preference.

The main objectives of this activity are:

- Increase agency of student in science learning process
- Critical thinking by analysis of scientific information
- Dialogue: working in groups to prepare the script. They share ideas and communicate what they learn
- Breaking stereotypes: science is boring and science is difficult, both statements are challenged by this activity where students have fun making others laugh with a science based script.
- Communication skills, arts. They create a video. They have to use different skills usually developed in the scenic arts plus audiovisual techniques.
- Connect and share with audience. Since audience is part of the jury of the contest, students have to reach as many people as possible, making them aware of the importance of high impact in communication of science.

3.2 General skills objectives

Since this activity is not focused in any particular field of science, general and specific objectives are the same.

4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The aim of the demonstrator is to give teachers a tool to increase motivation of students in science. Being an international contest for students and teachers motivation not only comes by the fact that students has the possibility to choose the topic they work with, but also the prize of the contest, being a trip to Bilbao to take part of the biggest science show in Spain, and the special prize of a trip to CERN were an art at CMS activity can be developed for this occasion.

4.2 Student needs addressed

The main need addressed is communication skills. Students usually finish their professional preparation with few or no experience in communication. Whereas communication is a crucial part of everyday work and life, education usually disregards this part of the learning process. In this activity students work their favourite science topic and they create their own script and they record it in front of the camara.

5 Learning Activities & Effective Learning Environments

Science topic: not specific (Relevance to national curriculum) Class information Year Group: secondary (1 ESO to 2 Bachillerato) Age range: 12-18 Sex: both Pupil Ability: all inclusive	Materials and Resources *What do you need? Students need a camara to record their performance, internet connection to upload it to internet.* *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one? It is an online contest* *Health and Safety implications? None* *Technology? Internet connection* *Teacher support? It is not required but suggested.*
Prior pupil knowledge **Not required**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will learn about different science topics, communication skills, how to share and increase the impact of your content.		
Assessment **Questionnaires will be available before and after the sessions**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* Since work can be both individual and in groups, it is easily adapted to their individual needs	**Key Concepts and Terminology** **Science terminology: any related to STEM careers** **Arts terminology: dramatization of science**
Session Objectives: During this scenario, students will have the ability to go in front of a group of people and explain better their knowledge.		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Students can use material offered by TBVT to find their preferred topic.	Teachers are given material to open questions that can motivate curiosity of students	**Videos and monologues can be part of the material**

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students search in books and on internet to get a better knowledge of their chosen topic.	Teachers offer information and complete the students knowledge of the chosen topic	**Videos and monologues will be available**
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	In groups or individually they work in the evidences to create a script	Teacher supervise the work in gruops	**This is part of the preparation of the script so arts are included in the own nature of the activity**
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.Students create a script where they explain what they have learnt in a funny way	Teachers complement the work of the students	**Since it is a dramatization, arts are part of this activity in this point**
Phase 5:	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both	In the whole process of creation of the script	. Teacher is guiding the	**The dramatization of the science topic is the**

CONNECT: students connect explanations to scientific knowledge	disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	they have to connect different ideas	process to connect ideas	**artistic part of this step**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Students perform in front of other students	Teacher guide the dialogue after the performance	**It is a performing activity**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Q&A follow the show, and this part is used to reflect about the whole process	Teacher guide the Q&A part	**It is again a performing based activity**

CREATIONS has received funding from the European Commission HORIZON2020 Programme

6 Additional Information

This is the second edition of this national contest. In previous years more than 200 videos in Spain were sent to the contest.

This national contest is organized in collaboration with NAUKAS (http://naukas.com/), the Catedra de Cultura Cientíica de la Universidad del País Vasco and TBVT.

Previous edition of this contest are available here:

http://cienciaclip.naukas.com/

7 Assessment

Questionnaires will be used to test the activity.

8 Possible Extension

This contest could be applied in an international level

9 References

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.99 Aspects of Venus

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH**
Code:	D 3.2.99.	**Contributors:**	
Version & Date:	Version 1.0, 2016-05-23	**Approved by:NKUA**	

CREATIONS has received funding from the European Commission HORIZON2020 Programme

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy, physics, chemistry, math, arts, language

1.2 Type of Activity

The activity is a combination of:

a) School based and
b) Science centre / research centre based

The activity is local in Stockholm, but can be extended to a national activity in Sweden.

1.3 Duration

1,5 – 3 hours

1.4 Setting (formal / informal learning)

The setting is both formal and informal. The activity involves preparation and follow-up work in the classroom, while the activity itself takes place in an informal setting.

Formal and informal learning settings

- Classroom
- Science centres
- Research centres
- Locations of planet models in Sweden Solar System

1.5 Effective Learning Environment

- Communities of practice (physical)
- Dialogic space / argumentation
- Arts-based
- Experimentation (Science laboratories)
- Visits to research centres (physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

Great challenges in astronomy education are understanding of:

- The vast distances involved
- Three-dimensional structures involved (Urban Eriksson 2014; Urban Eriksson et.al 2014).
- The night/day cycle
- The origin of seasons on Earth
- Phases of the inner planets
- Climate on planets / radiation balance
- The actual and apparent movement of objects in the sky

Some common misconceptions that we wish to address are e.g. that seasons are caused by variations in the distance to the Sun; that the moon and planets can only be seen at night; that the phases of the moon are caused by the shadow of the Earth.

2.2 Added Value

The purpose of the demonstrator is to combine science and arts to visualize complex astronomical phenomena in order to increase students' interest and understanding, and let them experience the vast distances in the Solar System. In order to do this we will use the worlds' largest scale model of the solar system – Sweden Solar System.

In Sweden Solar System (SSS), Globen in Stockholm, the largest spherical building in the world, represents the Sun. The planets are lined up in direction north from Globen. All the planets and a number of other astronomical objects are represented by artistic physical models. All models have been created by professional artists. Distances and sizes are scaled according to 1:20 million, and the inner planets are all in the Stockholm area. Although SSS has a great potential, it has up to now not been used much in education.

The demonstrator is grounded on the Collaborative learning approach (Roger Säljö, 2000; Vygotsky, 1978) in the form of group works that culminate in a presentation, which might be artistic or more scientific. In addition there are group works based on Inquiry Based learning where the groups by exploring small models of the planetary system discover the answers to previously given questions that are aimed at addressing some common misconceptions in astronomy.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Aspects of Venus (AoV) activity is to increase students' interest and knowledge in science, particularly astronomy, through the means of inquiry and different forms of artistic expression.

The AoV domain specific objectives are to:

- get students interested in science through artistic expression of astronomical questions
- initiate a discussion on different misconceptions in astronomy
- initiate contact between students and young scientists
- increase students' self-confidence in the subjects involved

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- formulate and revise scientific explanations and models using logic and evidence
- communicate and defend a scientific argument
- meet role models in the form of older students and young scientists

3.2 General skills objectives

In the context of the AoV, students' general skills objectives are:

- Active participation and engagement in the presentation of scientific concepts
- Understanding and applying the scientific inquiry approach
- Connecting science with arts
- Language skills
- Developing a spirit of cooperation and teamwork

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to improve students' understanding of the geometry and structure of the solar system, the movements of planetary bodies and how this can be observed, as well as how these effects affect us on Earth. By improving understanding of these phenomena, we aim to increase student interests for science in general and astronomy in particular.

4.2 Student needs addressed

In the demonstrator students identify relevant questions (within the given framework), investigate and experiment to construct knowledge in order to improve their understanding of certain astronomical phenomena that are often subject of misconceptions. The topic/question to illustrate and the form of the artistic expression are selected by the students. The freedom of the artistic expression is a challenging factor for students both in order to understand their scientific question and be engaged in collaborative discourse and creation.

5. Learning Activities & Effective Learning Environments

Science topic: Astronomy, physics, chemistry, mathematics **(Relevance to national curriculum) Swedish middle school curriculum** **Class information** **Year Group: 4th – 6th grade (middle school)** **Age range: 10-12 years** **Sex: Both** **Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)**	**Materials and Resources** ***What do you need?)*** **Small models of the solar system (Helios planetarium or similar, Tellurium), small telescopes. A model of Venus (part of Sweden Solar System), material about Sweden Solar System.** ***Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?*** **Preparatory and follow-up activities take place in schools. The activity itself takes place at Vetenskapens Hus in Stockholm.** ***Health and Safety implications?*** **None** ***Technology?*** **Telescope** ***Teacher support?*** **Scaffolding**
Prior pupil knowledge **Before the visit to Vetenskapens Hus the student should be familiar with the different components of the solar system.**	

Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)***
During this scenario, students will
Understand how the planets move with respect to each other and how this can be observed
Understand why the inner planets show phases
Understand the causes of the seasons on Earth
Get a feeling for the immense distances in the solar system and respective sizes of planets/Sun

Assessment	Differentiation	Key Concepts and Terminology
Through clicker questions we assess what the students have learned. **Student engagement during the activity will give an indication of their understanding and how inspired they become.**	*How can the activities be adapted to the needs of individual pupils?* **The activity will be adapted for different age groups as needed to take into account variation in prior knowledge between different groups.** **The activity is available to students with disabilities.**	**Science terminology:** Astronomy, Mathematics, Geometry, Physics, Chemistry **Arts terminology:** Performance, choreography, music

Session Objectives:
During this scenario, students will
Improve their understanding of the geometry and structure of the solar system, the movements of planetary bodies and how this can be observed, as well as how these effects affect us on Earth.
Meet inspiring role models in the form of older students who guide them during the activity.

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: QUESTION: students investigate a scientifically oriented question	Students are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	• Is given a theme for questions to investigate	• Will have a dialogue with the students to clarify and structure the question	• Creativity in formulating a scientific question by for example acting/poetry/dance
Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• Conduct simple investigations to explore the questions posed	• The teacher divides students into groups and guides the students as and when they need help • The teacher identifies possible misconceptions	

Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	• Students engage in analysing data by interpreting what they observe	• Acts as a facilitator of the process	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	• With the help of experiments students formulate an explanation of the observed phenomena in light of the posed question.	• Acts as a facilitator of the process	• Creativity in describing a phenomenon by for example acting/poetry/dance
Phase 5: **CONNECT: students connect explanations to scientific knowledge**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	• Connect explanations from experiments with the artwork in Sweden Solar System	• Encourages interdisciplinarity in explanations by pointing out connections to	

			art and other disciplines	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	• Students communicate with each other and with tutors (university students) in order to get help with their investigations • Students communicate their inquiry findings by discussion with the tutor and	• Assess students' understanding • Aid students in interpretation of observations, adjusting the help according to the students' level of understanding.	

		their teacher		
Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• As a conclusion of the activity the whole class reflects together on their findings and the implications for the answers to the posed questions.	• Take part in the final reflection together with the students. • Assess students' understanding.	• Art is used as a help to visualize and reflect on the distances and scales of the solar system

6. Additional Information

The activity consists of four parts:

1) An artistic activity centred on the model of the planet Venus situated at Vetenskapens Hus in Stockholm
2) An inquiry based activity focusing on some common misconceptions regarding motions and observations of planets and the moon.
3) A guided tour of the observatory
4) Short lecture and final reflective summary

1) Artistic activity

At the start of the activity the students gather around the model of Venus. The tutor (a university student) briefly presents the SSS and the model of Venus in particular. The five plates surrounding the model of the planet are described, with a short explanation of which aspect each plate represents.

Photo of the model of Venus in Sweden Solar System

2) Inquiry

In this part of the activity the students (in groups of 2-3) investigate certain given questions with the aid of small models of the solar system. The questions to investigate focus on the motions of the planets, the cause of the phases of the moon and inner planets, the times when the moon and planets can be observed and the cause of seasons.

Photo of students working with a model of the solar system

3) Guided tour

The students are given a short guided tour to the observatory, where they also get to visit the roof and look at Globen to see how far away it is. The distances are discussed, and if possible the students get the chance to observe Venus or other planets through the telescope.

Photo from inside of the dome at the observatory during a guided tour with students

4) Lecture/discussion

As a conclusion a short lecture on the solar system, both the actual and the model, is given by the tutor. The students get the opportunity to talk about and reflect on their findings and connect this to the questions posed.

Relevant links:

Sweden Solar System: http://www.swedensolarsystem.se/en/

7. Assessment

Assessed according to the Swedish middle school curriculum.

Students' understanding is assessed with the aid of electronic clickers, as well as from the students' engagement with the activities.

The teachers assess the activity through a questionnaire where they are asked to evaluate the scientific and pedagogical value of the whole activity as well as its connection to the Swedish middle school curriculum.

8. Possible Extension

The activity can be extended to an activity in a school setting as well as to a national or even international event. It can also easily be extended to other age groups. We envisage the following possibilities for extension:

- Planets on a string – scale model of planets sizes for younger pupils (in school setting)
- Create their own scaled-down solar system in the school vicinity by doing the relevant calculations – older children (in school setting)
- Doing similar activities centred on other planet models in Sweden Solar System (informal setting)
- In collaboration with science centres in other Scandinavian countries, do similar activities at relevant distances from Stockholm in other countries.

9. References

Urban Eriksson (2014), *Reading the Sky - From Starspots to Spotting Stars,* Thesis Uppsala university, ISBN 978-91-554-9086-7

Urban Eriksson, Cedric Linder, John Airey, Andreas Redfors (2014), *Who needs 3D when the Universe is flat?* Science Education, 2014, Vol.98(3), pp.412-442

Säljö, Roger (2000). *Lärande i praktiken: Ett sociokulturellt perspektiv*. Stockholm: Norstedts Akademiska Förlag.

Lev Vygotsky (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

D3.2.100 Astronomy Day and Night at Vetenskapens Hus

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH
Code:	D 3.2.100.	**Contributors:**	
Version & Date:	Version 1.3, 2018-02-06	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy, physics, technology, arts

1.2 Type of Activity

The activity focuses on the direct collaboration between families and research centre.

The activity is local in Stockholm, but is part of a large national activity in Sweden.

1.3 Duration

1 day at research centre / university

1.4 Setting (formal / informal learning)

The setting is informal:

- Science centres
- Research centre / university

1.5 Effective Learning Environment

- Dialogic space / argumentation
- Arts-based
- Experimentation (science laboratories)
- Visits to research centre (physical)

CREATIONS has received funding from the European Commission HORIZON2020 Programme

2. Rational of the Activity / Educational Approach

2.1 Challenge

Astronomy is a field that both children and adults find fascinating, and the interest for astronomy and space physics among the general public is great. However, astronomy also involves many abstract concepts which may be hard to grasp, and therefore leads to a number of misconceptions. The aim of this activity is to make the latest research more accessible to the general public through meetings with scientists as well to inspire visitors - particularly children - through visits to research laboratories and observatories and hands-on astronomy activities.

2.2 Added Value

This activity aims to inspire children to a general interest in science and technology through the use of astronomy and arts.

The visitors are given the opportunity to interact with researchers and university students. Through hands-on activities and communication and reflection with each other as well as with scientist they will construct their own knowledge and understanding at a level appropriate for each visitor.

With the aid of artistic activities we also aim to facilitate the understanding of certain difficult concepts and to eliminate some common misconceptions.

The demonstrator is within the field of museum education with the aim to develop and strengthen the educational role of non-formal education spaces (AlmaDis Kristinsdottir 2017, Griffin, J. 2012, Rennie, L. J. & McClafferty, T. 1995).

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Astronomy Day and Night (ADN) activity is to increase the interest, curiosity and understanding for astronomy among the general public, through a combination of lectures, hands-on activities, guided tours and demonstrations.

The ADN domain specific objectives are to:

- give the general public a chance to interact with astronomy researchers
- initiate a discussion on different misconceptions in astronomy
- increase children's self-confidence in the subjects involved
- inspire the public through visits to research laboratories

Towards attaining these objectives, peripheral aims are formed addressing visitors' needs to:

- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations

- formulate and revise scientific explanations and models using logic and evidence
- communicate and defend a scientific argument
- meet role models in the form of students and scientists

3.2 General skills objectives

In the context of the ADN, visitors' general skills objectives are:

- Active participation and engagement in the presentation of scientific concepts
- Understanding of scientific concepts and phenomena
- Understanding and applying the scientific inquiry approach
- Connecting astronomy with arts
- Language skills

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the "Astronomy Day and Night at Vetenskapens Hus" (ADN) activity is to engage the general public through lectures and hands-on activities based on current astronomical research. A strong focus is placed on activities for children in all age groups. The visitors get the opportunity to learn astronomy through hands-on activities and interactions with researchers and university students, as well as through art.

The main objective of the demonstrator is to engage the visitors in learning experiences to enhance their curiosity and interest in astronomy.

4.2 Student needs addressed

In the demonstrator visitors identify relevant questions (within the given framework), investigate and experiment to construct knowledge in order to improve their understanding of certain astronomical phenomena and clarify misconceptions. The topic/question to illustrate and the form of the artistic expression are selected by the visitors. The freedom of the artistic expression is a challenging factor for visitors both in order to understand their scientific question and be engaged in collaborative discourse and creation.

The visitors' needs were taken into consideration in the design of the activities. As the visitors were of all ages, from about 2-90 years, the activities varied to suit different ages. They were also adapted to promote collaborations and discussions between for example parents and children, grandparents and grandchildren.

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5. Learning Activities & Effective Learning Environments

Science topic: Astronomy, physics (Relevance to national curriculum) Not applicable Class information Year Group: Not applicable (general public) Age range: 2-90 years Sex: Both Pupil Ability: Mixed (The scenario allows space for visitors of various abilities to participate)	Materials and Resources *What do you need?* **Telescopes, small models of the solar system (Helios planetarium), computers, material for arts workshop (paint, paper, pearls, modelling clay, scissors, glue, glitter etc). Laboratories and lecture halls with projectors.** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **At Vetenskapens Hus and AlbaNova University Center in Stockholm** *Health and Safety implications?* **None** *Technology?* **Telescopes, computers** *Teacher support?* **Instructing, guiding and scaffolding during hands-on activities and guided tours, dialogue during lectures.**
Prior pupil knowledge: No prior knowledge necessary, the workshops will be adapted to the audience.	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, visitors will

Learn about the latest research in astronomy.

Understand how the planets move with respect to each other and how this can be observed.

Perform measurments of the solar spectrum and determine the temperature of the Sun.

Understand how planets around other stars can be detected.

Get a feeling for the immense distances in the solar system and respective sizes of planets/Sun.

Assessment	**Differentiation**	**Key Concepts and Terminology**
The effect of the intervention will be assessed through visitors' engagement during the event, and through discussion during workshops and lectures.	*How can the activities be adapted to the needs of individual pupils?* **The activity is available to visitors with disabilities.**	**Science terminology:** Astronomy, physics, engineering **Arts terminology:**

The CREATIONS evaluation for the visitors used is the Science Motivation Questionnaire for Students. • the short SMQII – questionnaire both as pre- and post-test.		Performance, design
Session Objectives: During this scenario, visitors will		

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and	• Visitors will do hands-on activities	During each hands-on activity the tutor or researcher will present the scientific	• Visitors will create their own

scientifically oriented question	students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	where scientific questions posed by the tutor or researcher will be explored • Visitors engage with lecturers through questions and discussion	questions to be explored, and is available for assistance during the activity.	representations of an astronomical phenomenon through drawing, sculpture or other artistic expression.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• In some of the activities visitors will perform real observations, or explore real data from astronomical observatories. This is done through	The tutors and researchers are available for discussions and support during the observations and data analysis.	

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		practical work, either individually or in collaboration with others, as well as in interaction with the teacher.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Visitors will analyse data from their own observations of the solar spectrum, and observations provided by the	Scaffolding and dialogue with the tutor or researcher	

		guide where they will investigate the presence of exoplanets.		
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Visitors will use the data they have analysed to determine the temperature and composition of the Sun, and the presence of exoplanets in some other solar systems	The tutors and researchers guide and discuss, to aid visitors in constructing explanations, posting the question "what if…." to help visitors investigate different possibilities.	The hands-on workshops could be combined with art-workshops where visitors illustrate an astronomical phenomenon of their own choice, by combining the artistic activity with the results of their own analysis.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Visitors use the results of their own analysis and the information they get from the lecturers to connect their knowledge	Discuss the various possible explanations, providing scientific knowledge to help visitors connect their ideas to current science.	

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		between disciplines.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	• The visitors interact and engage with tutors and researchers to discuss the explanations of what they observe and other astronomical questions.	The tutors and researchers discuss with visitors and adapt the content to the relevant age group.	**Communication of ideas and explanations could be done through various artistic activities, such as a play, song, dance, painting, sculpture or other artforms of their own choice.**
Phase 7: **REFLECT:** students reflect on the inquiry	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• The visitors interact and engage with tutors and researchers to discuss the	The tutors and researchers engage with visitors to discuss and reflect on the	

process and their learning		explanations of what they observe and other astronomical questions.	observations and various astronomical phenomena.	

6. Additional Information

http://www.vetenskapenshus.se/adon-astronomins-dag

http://www.astronominsdag.se/

Agenda for the Astronomy Day and Night on September 23 2017:

Activities for all ages

- Go to space with Kerbal Space program
- Discover the solar system with planetarium models
- Build your own solar system
- Study sunspots and observe the Sun

Lectures by university scientists

- 11.30 – 12.00: The extraordinary stellar explosion PTF16geu
- 12.30 – 13.00: A brief overview of the greatest mysteries of the Universe
- 14.30 – 15.00: My space journey
- 15.30 – 16.00: Black holes: on the darkest, and brightest, objects of the Universe

Demonstrations

Observations with the solar telescope at Vetenskapens Hus (continuously)

The telescope at AlbaNova (once every hour)

The model of the planet Venus (once every hour)


7. Assessment

The effect of the intervention will be assessed through visitors' engagement during the event, and through discussion during workshops and lectures.

The CREATIONS evaluation for the visitors used is the Science Motivation Questionnaire for Students.

- the short SMQII – questionnaire both as pre- and post-test.

8. Possible Extension

The activity is part of a national event, arranged at different sites in Sweden. Through collaboration between the organizers at different locations the national focus of the event could be strengthened.

9. References

AlmaDis Kristinsdottir (2017) Toward sustainable museum education practices: confronting challenges and uncertainties, Museum Management and Curatorship, 32:5, 424-439, DOI: 10.1080/09647775.2016.1250104

Griffin, J. (2012) in "Understanding interactions at science centers and museums", Davidsson E. & Jakobsson, A. (eds.), Sense Publishers , s. 115-128

Rennie, L. J. & McClafferty, T. (1995), "Using visits to interactive science and technology centers, museums, aquaria, and zoos to promote learning in science", Journal of Science Teacher Education, vol 6, no 4, 175-185

Relevant links:

http://www.astronominsdag.se/

CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.101 Features of the Sun

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH**
Code:	D 3.2.101.	**Contributors:**	
Version & Date:	Version 1.4, 2018-02-06	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy, physics, chemistry, math, arts, language

1.2 Type of Activity

The activity is a combination of:

c) School based (an educational activity based on creativity-enriched Inquiry Based Approaches) and
d) Science centre / research centre based (an educational activity that promotes school-research center collaboration)

The activity is local in Stockholm, but can be extended to a national activity in Sweden.

1.3 Duration

About 3-8 hours

1.4 Setting (formal / informal learning)

The setting is both formal and informal. The activity involves preparation and follow-up work in the classroom, while the activity itself takes place in an informal setting.

Formal and informal learning settings

- Classroom
- Science centres
- Location of the Sun in Sweden Solar System (Globen) (Optional)

1.5 Effective Learning Environment

- Communities of practice (physical)
- Dialogic space / argumentation
- Arts-based
- Experimentation (Science laboratories)
- Visits to science centre (physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

The main challenge is the lack of interest and motivation in science education in general and in this demonstrator we specifically focus on physical science in the area of astronomy. A challenge is also to promote 21st century skills such as problem solving and teamwork. In this demonstrator art and science are promoted through activities in the field of astronomy. Astronomy is a very visual field that engages many young people. Beautiful pictures and fascinating objects, such as black holes, vast distances stimulates the fantasy and engages young people in creativity and art.

The benefits for the society are increased interest in science and technology, improved science literacy as well as increased science capital (Archer et al 2015), and the promotion of general skills such as problem solving and teamwork.

Great challenges in astronomy education, specifically, are understanding of:

- The vast distances involved and sizes of astronomical objects. The distances and sizes in the universe are immense and very hard to grasp. By studying and experiencing a scaled down model of the solar system gives the students a way to experience the vastness and emptiness of our solar system.
- Three-dimensional structures involved (Urban Eriksson 2014; Urban Eriksson et.al 2014). Three-dimensional features can be difficult and are often projected onto two-dimensional pages. By engaging in a three-dimensional model some three-dimensional structures appear more clearly.
- The Sun as a star. Stars appear as faint dots on a dark night sky, while the Sun shines strongly during daytime. Due to their different appearances it is not obvious that these are the same type of objects.
- The influence of the Sun on the Earth. The Sun influences us on Earth in many ways. The most obvious ways are day and night. The way the seasons are formed is often misunderstood as it depends on the angle of the axis of the Earth and has nothing to do with the distance to the Sun. Aurora is a phenomena which is formed by particles in the solar wind.
- The actual and apparent movement of objects in the sky. Motions of the planets around the Sun, the Moon around the Earth, the rotation of the Earth and Sun etc. are examples of motions in the solar system that results in different observations. In order to understand a

phenomenon such as for example a solar eclipse an understanding of the motions in the solar system is required.

By combining astronomy and art we aim to overcome some of the above-mentioned challenges by promoting interest and motivation using artwork *Sweden Solar System* to visualize the vastness and emptiness of the solar system (http://www.swedensolarsystem.se/en/).

2.2 Added Value

The purpose of the demonstrator is to combine science and arts to visualize complex astronomical phenomena in order to increase students' interest and understanding, and let them experience the vast distances in the Solar System. In order to do this we will use the worlds' largest scale model of the solar system – Sweden Solar System.

The students benefit from combining art and astronomy through helping them visualize and understand complex phenomena and distances both with the help of Sweden Solar System and through the creativity in doing their own pieces of art.

In Sweden Solar System (SSS), Globen in Stockholm, the largest spherical building in the world, represents the Sun. The planets are lined up in direction north from Globen. All the planets and a number of other astronomical objects are represented by artistic physical models. All models have been created by professional artists. Distances and sizes are scaled according to 1:20 million, and the inner planets are all in the Stockholm area. Although SSS has a great potential, it has up to now not been used much in education. The pedagogical strength of using the Sweden Solar System is to let the students experience the vast emptiness and distances of the solar system.

The demonstrator is based on the Collaborative learning approach (Roger Säljö, 2000; Vygotsky, 1978) in the form of group works both in the classroom and in a science centre. The group works are based both on artistic and scientific approaches. Using inquiry-based learning the students investigate some features of the Sun and their sizes. By modelling students investigate some central features of the Sun as; solar spots, solar eclipse, aurora, solar wind, temperatures and colours of stars/Sun.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Features of the Sun (FoS) activity is to increase students' interest and knowledge in science, particularly astronomy, through the means of inquiry and different forms of artistic expression.

The FoS domain specific objectives are to:

- get students interested in science through artistic expression of astronomical questions
- increase the students understanding of the Sun as a star, the reasons for seasons, the cause of day and night and other way the Sun may influence the Earth
- increase the students understanding of the structure and movements in the the solar system

- estimate the distances in the solar system and sizes of astronomical objects
- initiate a discussion on different misconceptions in astronomy
- initiate contact between students and young scientists
- increase students' self-confidence in the subjects involved

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- formulate and revise scientific explanations and models using logic and evidence
- communicate and defend a scientific argument
- meet role models in the form of older students and young scientists

3.2 General skills objectives

In the context of the FoS, students' general skills objectives are:

- Active participation and engagement in the presentation of scientific concepts, which develop a spirit of cooperation and teamwork. During the active participation and teamwork the students learn to fully support their hypotheses with strong scientific evidence, they also listen to each other and finally they come to a common decision together.
- Connecting science with arts. By representing some central features of the Sun and how it affects us at Earth they will learn how to communicate scientific knowledge supported by evidence.
- Language skills. New scientific concepts are presented and used as they discuss and present their concepts.
- Understanding and applying the scientific inquiry approach
- Understanding of scientific concepts and phenomena

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to increase the students' interest and motivation in science education in general and specifically in the area of astronomy. Other aims are also to promote the practice of general skills such as problem solving and teamwork. By combining art and science the aim is to improve students' understanding of the three-dimensional geometry, structure and distances in the solar system, the sizes of astronomical objects, the actual and apparent motions of objects on the sky, different features on the surface of the Sun, how they can be observed, as well as how they affect us on Earth (such as seasons and the cause of day and night). By improving understanding of these phenomena through the opportunity to use art in a creative way, we aim to increase student interests for science in general and astronomy in particular.

4.2 Student needs addressed

In the demonstrator students identify relevant questions (within the given framework), investigate and experiment to construct knowledge in order to improve their understanding of certain astronomical phenomena that are often subject of misconceptions. The topic/question to illustrate and the form of the artistic expression are selected by the students. The freedom of the artistic expression is a challenging factor for students both in order to understand their scientific question and be engaged in collaborative discourse and creation.

The students may use different artistic expressions such as acting, dancing, modelling, drawing, etc to understand and learn about some features of the Sun (solar spots and prominences, solar wind, aurora, solar eclipse, colours and temperatures of the Sun/stars). They produce an artistic representation, which they share and discuss with other students to clarify the notions and concepts.

The students also pose scientific questions about solar spots. By conducting simple investigations and measurements on astronomical pictures they explore the question. The data used are astronomical observations of the solar surface. With the help of the investigation and data they formulate explanations based on evidence. They connect explanations to scientific knowledge and communicate with other students. This communication may be done using artistic expressions. At the end of the activity the whole class reflects together on their findings and the implications for the answers to the posed questions.

5. Learning Activities & Effective Learning Environments

<table>
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Science topic: Astronomy, physics, chemistry, mathematics

(Relevance to national curriculum) Swedish middle school curriculum

Class information

Year Group: 7th – 9th grade (middle school)

Age range: 13-16 years

Sex: Both

Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)

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Materials and Resources

What do you need?
Sunspotters, solar telescopes, computers, material about Sweden Solar System

Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?

Preparatory and follow-up activities take place in schools. The main activities take place at the Globe Arena (optional visit) and at Vetenskapens Hus in Stockholm.

Health and Safety implications?

Care should be taken when observing the Sun

Technology?

Telescope, computers

Teacher support?

Scaffolding

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Prior pupil knowledge

Before the visit to Vetenskapens Hus the student should be familiar with the different components of the solar system.

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Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?***The activity consists of three part:**

5) An artistic activity centred on the model of the Sun in Sweden Solar System

The students learn about:

- **the Sun as a star, its energy generation and evolution**
- **sunspots and other features (such as sunspots, prominences, colour, solar wind, solar eclipse, Aurora and space weather) on the surface of the Sun, their sizes and structure**

6) An inquiry based activity focusing on some features of the Sun, size and distance and how the Sun affects Earth.

The students learn about:

- **sizes and distances in the solar system,**
- **the reasons for seasons and day and night**

7) **An inquiry based activity focusing on the observations of the solar surface to examine sunspots and their motions across the solar surface**.

The students learn about:

sunspots and their motions across the solar surface

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Assessment **Through clicker questions we assess what the students have learned.** **Student engagement during the activity will give an indication of their understanding and how inspired they become.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* **The activity will be adapted for different age groups as needed to take into account variation in prior knowledge between different groups.** **The activity is available to students with disabilities.**	**Key Concepts and Terminology** **Science terminology:** Astronomy, Mathematics, Geometry, Physics, Chemistry **Arts terminology:** Performance, choreography, music

Session Objectives: During this scenario, students will **Improve their understanding of the geometry and structure of the solar system, different features on the surface of the Sun and how this can be observed, as well as how these effects affect us on Earth.** **Get a feeling for the immense distances in the solar system and respective sizes of planets/Sun.** **Meet inspiring role models in the form of older students who guide them during the activity.**				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental	• Is given a theme for questions to investigate	• Will have a dialogue with the students to clarify and structure the question	• Creativity in formulating a scientific question by for example drawing, photography,

	design and collaborative work, as well as in the initial choice of question.			movies or stories
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• Conduct simple investigations to explore the questions posed	• The teacher divides students into groups and guides the students as and when they need help • The teacher identifies possible misconceptions	
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	• Students engage in analysing data by interpreting what they observe	• Acts as a facilitator of the process	
Phase 4:	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative	• With the help of observations	• Acts as a facilitator of the process	• Creativity in describing a phenomenon by for

EXPLAIN: students formulate an explanation based on evidence	merits of the explanations they formulate, *playing* with ideas.	students formulate an explanation of the observed phenomena in light of the posed question.		example drawing, photography, movies or stories, choreography.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	• Connect explanations from experiments with the artwork in Sweden Solar System	• Encourages interdisciplinarity in explanations by pointing out connections to art and other disciplines	
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of	• Students communicate with each other and with tutors	• Assess students' understanding • Aid students in interpretation of observations, adjusting the	

COMMUNICATE: students communicate and justify explanation	the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	(university students) in order to get help with their investigations • Students communicate their inquiry findings by discussion with the tutor and their teacher	help according to the students' level of understanding.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• As a conclusion of the activity the whole class reflects together on their findings and the	• Take part in the final reflection together with the students.	• Art is used as a help to visualize and reflect on the distances and scales of the solar system

		implications for the answers to the posed questions.	• Assess students' understanding.	

6. Additional Information

Below follows a more detailed description of the activity, which can be useful for anyone wanting to work with this demonstrator with his or her own students.

The activity consists of three parts:

1) An artistic activity centred on the model of the Sun represented by Globen situated in central Stockholm with the aim to illustrate a feature of the Sun (sunspots, prominences, colour, solar wind, solar eclipse, Aurora and space weather).
2) An inquiry based activity focusing on some features of the Sun, size and distance and how the Sun affects Earth.
3) An inquiry based activity focusing on the observations of the solar surface to examine sunspots and their motions across the solar surface.

1) Artistic activity

The teacher prepares the class with the help of material produced for this demonstrator. The material consist of information material about the Sun in Sweden Solar System represented by Globen, and of descriptions of five features that characterize the Sun:

- Sunspots and prominences
- Colour and temperature
- Solar wind
- Solar eclipse
- Aurora and space weather

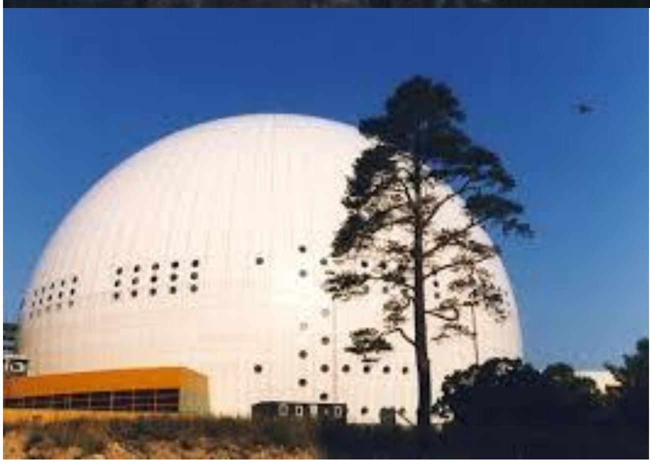
An optional class visit to Globen where the students

- take pictures and/or film other students at different locations w.r.t the Globe
- measure the sizes of the windows relative to the size of Globe.
- try to identify 'sunspots' and 'prominences'

Back in the classroom the students work with their pictures or with the material provided for the demonstrator.

Divide the class into 5 groups. Let each group work with one of the features and explain it using their photos of Globen (representing the Sun) or with the photos provided for the demonstrator in combination with drawings or other art forms.

Material needed: Information about the Sun in Sweden Solar System represented by Globen and photos of Globen. 5 short summaries including pictures describing the 5 features of the Sun.



Globen, which represents the Sun in Sweden Solar System

2) Inquiry based activity at research centre

During a visit to Vetenskapens Hus the students explore the surface of the Sun using astronomical pictures. The sizes of sunspots will be measured and compared to the size of the Earth.

On sunny days the surface of the Sun will be observed with a solar telescope and they will be able to observe the number and sizes of sunspots.

A lecture presenting the Sun. Discussions and reflections about their observations

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The solar telescope at Vetenskapens Hus

3) An inquiry based activity in the classroom

By projecting the solar surface on a piece of paper and drawing the location of sunspots the students are able to follow the motion of the sunspots across the solar surface during a period of 1-2 weeks.

Questions to investigate:

- Does the number of sunspots vary?
- How quickly do the sunspots move across the surface?
- Does the motion of sunspots vary with latitude?
- Compare your observations with data from spaceweather.com.

Material needed: Description of how to observe the Sun safely by projecting the image on a paper.

Safe observations of the Sun.

Relevant links:

Sweden Solar System: http://www.swedensolarsystem.se/en/

www.spaceweather.com

7. Assessment

Assessed according to the Swedish school curriculum for year 7-9:

Physics:

Through teaching in the subject of physics, students will be given the opportunity to develop their ability to

• carry out systematic investigations in physics, and

• use the concepts, models and theories of physics to describe and explain physical relationships in nature and society.

Central content

• The structure of the universe with celestial bodies, solar systems and galaxies, as well as movements and distances between them.

• Systematic investiations. Formulation of simple questions, planning, execution and evaluation.

• The connection between physical examinations and the development of concepts, models and theories.

Swedish:

Through teaching in the subject of swedish, students will be given the opportunity to develop their ability to

- *formulate and communicate in spoken and written terms*
- *adapt the language to different purposes, recipients and contexts*

Central content

- *Oral presentations and oral narratives for different recipients.*

Art:

Purpose:

- *Through education, students will gain experience of visual culture in which film, photography, design, art, architecture and environments are included.*
- *Teaching will help students develop their creativity and their interest in creating. It will also encourage students to take their own initiative and to work in an investigative and problem-solving manner.*

Through teaching in the subject of art, students will be given the opportunity to develop their ability to

- *Communicate with pictures to express messages*
- *Explore and present different subject areas using pictures*

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Students' understanding is assessed with the aid of electronic clickers, as well as from the students' engagement with the activities.

The teachers assess the activity through a questionnaire where they are asked to evaluate the scientific and pedagogical value of the whole activity as well as its connection to the Swedish school curriculum.

The CREATIONS evaluation for the students used is the Science Motivation Questionnaire for Students. Either

- the pre-test contain questions from SMQII, questions about problem-solving, as well as a visual test. The post-test contain questions from SMQII, questions about problem-solving, Intrinsic Motivation Questionnaire, and a visual test, or
- the short SMQII – questionnaire both as pre- and post-test.

Link to the pre-test: https://goo.gl/forms/5wMv76wFtbGOJo7G2

Link to the post-test: https://goo.gl/forms/ONDQSBFIkV72tKcj2

8. Possible Extension

The activity can be extended to an activity in a school setting as well as to a national or even international event. It can also easily be extended to other age groups. We envisage the following possibilities for extension:

- Planets on a string – scale model of planets sizes for younger pupils (in school setting)
- Create their own scaled-down solar system in the school vicinity by doing the relevant calculations – older children (in school setting)
- Doing similar activities centred on other planet models in Sweden Solar System (informal setting)
- In collaboration with science centres in other Scandinavian countries, do similar activities at relevant distances from Stockholm in other countries.

9. References

Archer, L. et al (2015), *"Science capital": A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts,* JRST, Volume 52, Issue 7 Pages 922–948

Urban Eriksson (2014), *Reading the Sky - From Starspots to Spotting Stars,* Thesis Uppsala university, ISBN 978-91-554-9086-7

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Säljö, Roger (2000). *Lärande i praktiken: Ett sociokulturellt perspektiv*. Stockholm: Norstedts Akademiska Förlag.

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CREATIONS Developing an Engaging Science Classroom	**D3.2 CREATIONS Demonstrators**

D3.2.102 Stockholm Pi-day

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH**
Code:	D 3. 103.	**Contributors:**	
Version & Date:	Version 1.4, 2018-02-12	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Mathematics, arts

1.2 Type of Activity

The activity is Science centre / research centre based, that promotes school-research center collaboration.

The activity is local in Stockholm.

1.3 Duration

Activities are arranged during a full day. One activity/seminar lasts about 1-3 hours.

1.4 Setting (formal / informal learning)

The setting is informal at a science /research centre.

1.5 Effective Learning Environment

- Communities of practice (physical)
- Dialogic space / argumentation
- Arts-based
- Experimentation
- Visits to science centre (physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

One of the main problems of science education today is young people's lack of interest in pursuing careers in science and mathematics. In addition, national tests (PISA, TIMSS) have shown that Swedish pupils' understanding of mathematics has decreased during the past decades. In order to overcome these problems, we need to promote motivation for studies of the physical sciences and mathematics, as well as increase the pupils' interest and self-confidence.

The challenges are

- to increase young peoples interest, knowledge and self-confidence in their own ability to solve mathematical problems.

- to increase the number of students continuing into university studies in mathematics, science and engineering.

- to increase a general mathematical literacy among the public.

2.2 Added Value

During the Pi-day

- we offer problem-solving activities to inspire young people, and problem solving is also a central part of the Swedish curriculum in mathematics
- alternative ways to teach mathematics through laboratory exercises are presented
- researchers in mathematics inform about research in the subject (connection to university researchers)
- seminars are given about how mathematics is used in every day life
- university students inform about different organizations that offer help to younger pupils in mathematics
- an art exhibition was displayed, where young people had painted their idea of mathematics, with the purpose to inspire and show young people the beauty of mathematics

Problem solving is a creative process, which involves seeking and applying knowledge in order to understand the problem and identify various solutions. By testing their solutions and evaluating the results, the students construct new knowledge.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Pi-day is to increase students' interest and knowledge in mathematics through the means of inquiry, lectures and different forms of artistic expression.

The Pi-day domain specific objectives are to:

- to show young people that mathematics is a fundamental science which is used in all other sciences and aspects of society
- to show young people that mathematics is a creative endeavour
- get students interested in mathematics and science through artistic expression
- depicting mathematical concepts through art, e.g. painting, drawing, 3D-printing or computer simulations (images).
- initiate contact between K-12 students and scientists in mathematics
- increase students' self-confidence in mathematics
- inform upper secondary school students about university programs in mathematics
- engage young people in problem solving activities by letting them
    - seek and apply mathematical knowledge in order to understand the problem
    - identify various solutions
    - collaborate with their peers on solving problems
    - test and evaluate their results
    - communicate their results to their peers and teachers
    - discuss and defend their findings.

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop understandings about scientific inquiry and mathematical problem-solving
- identify questions and concepts that guide scientific investigations
- formulate and revise scientific explanations and models using logic and evidence
- communicate and defend a scientific argument
- meet role models in the form of older students and young scientists

3.2 General skills objectives

In the context of the Pi-day, students' general skills objectives are:

- Active participation and engagement in the presentation of mathematical concepts
- Understanding and applying the scientific inquiry approach
- Understanding the presence of mathematics in the students every day life
- Connecting mathematics with arts
- Language skills
- Developing a spirit of cooperation and teamwork

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to improve students' interest in and understanding of problem solving, mathematics and its relevance for their everyday life, and to show them that mathematics is a creative endeavour. By collaborating and arranging the Pi-day together with two big universities we want to show K-12 students the beauty and importance of mathematics by letting them try different activities in an informal setting and through dialogue with scientists and university students.

In their meeting with university students and scientists the K-12 students also get information about further university studies in mathematics, science and engineering.

4.2 Student needs addressed

During the Pi-day students identify relevant questions (within the given framework), investigate and experiment to construct knowledge in order to improve their understanding of mathematical problems. Students' self-confidence in solving problems is enhanced through practical mathematical activities. The RRI aspects addressed are mainly "Science education engagement", "Gender equality" and "Open access / open science", while the CREATION features involved are "Dialogue", "Individual, collaborative and communal activities for change", "Empowerment and agency" and "Risk, immersion and play". These are applied both in the seminars, the meetings with university students, art exhibition as well as in the practical moments. Also the IBSE features are applied in the laboratory exercises and problem-solving activities. Through the use of dialogue and collaboration the students will exercise their communicative skills and through discussion with their peers and teachers will engage in analysis and problem-solving leading to an improved understanding and increased interest.

Through practical activities focussing on mathematical concepts and strategies the students combine dialogue, discussion, teamwork and mathematical reasoning to solve problems involving e.g. John Conway's tangles, binary coding and cryptography, as well as topology.

5. Learning Activities & Effective Learning Environments

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: Mathematics Class information Year Group: 7th – 9th grade and upper secondary school Age range: 13-19 years Sex: Both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need?* Laboratory mathematical, and problem solving, material such as blocks and binary boxes et Space and material for the mathematical exhibition such as - Imaginary (software) - Computers, screens, tables - 3D-printers - Rubik cubes - Space to put the art pieces - Quiz *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* The activities take place on parallel sessions at the university campus/Vetenskapens Hus in Stockholm. Spaces needed are: - Exhibition space - Lecture rooms - Laboratories *Health and Safety implications?* None *Technology?* Computers, network, AV-components *Teacher support?*

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Prior pupil knowledge Before the visit to Vetenskapens Hus and the university campus no specific mathematical knowledge is required as the activities is chosen, or adapted to the age of the pupils. However, we suggest the teachers to prepare the pupils by informing them about the agenda and the content of the lectures.		
Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this day, the students will - gain knowledge within the different mathematical topics presented (seminars) - gain knowledge about mathematical problem-solving (problem-solving activities, seminars) - receive information about university programs in mathematics (in meeting with university students and researchers) - increase their self-confidence in mathematics (problem-solving activities) - understand that mathematics is a creative endeavour (problem-solving activities, math-art exhibition)		
Assessment Student engagement during the activity will give an indication of their understanding and how inspired they become. This is assessed through discussion between students and tutors, as well as through the questions asked by the students and observations of the extent to which the	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* The activity will be adapted for different age groups as needed to take into account variation in prior knowledge between different groups. The activities are chosen and adapted in communication with the teachers.	**Key Concepts and Terminology** **Science terminology:** Mathematics, pi, graphs, simulations, topology, algebra, encoding, encryption, logic **Arts terminology:** Art, visualization, depicting

students take active part in problem solving and creative activities.	The activity is available to students with disabilities.	

Session Objectives:

During this scenario, students will

- Improve their understanding and knowledge of different mathematical topics and concepts.
- Increase their self-confidence in mathematics
- Get en understanding of the presence of math in their everyday life
- Meet inspiring role models in the form of older students who guide them during the problem-solving activities and in the exhibition.
- Develop a spirit of cooperation and teamwork

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1:	Students are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational	• Is given a mathematical problem to	• Will have a dialogue with the students to	• Creativity in depicting a

QUESTION: students investigate a scientifically oriented question	tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	discuss and solve	clarify and structure the mathematical problem	mathematical concept through drawing or painting.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• The students investigate, explore and do practical work to solve the mathematical problems. The problem-solving is often done in groups. In their investigation they are supported by	• The teacher divides students into groups and guides the students as and when they need help • The teacher identifies possible difficulties	

		the observations/ evidence.		
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	• Students engage in analysing data by interpreting what they observe.	• Acts as a facilitator of the process	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	• With the help of observations (and the discussion with university students, tutors) the students formulate an explanation to the posed mathematical	• Acts as a facilitator of the process	• Creativity in describing or visualizing a mathematical concept by for example painting or computer software (imaginary).

		problem based on the problem-solving activity.		
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	• Connect explanations from discussions with university students and researcher, practical mathematical problem solving. Mathematical problems are related to their every day life and how they can be applied to different	• Encourages interdisciplinarity by pointing out how math can be used in other disciplines as well as in art.	

		subjects, both in natural an social sciences.		
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	• Students communicate with each other and with tutors in order to solve their mathematical problem. • Students communicate with researchers to put the math in every day life context.	• Assess students' understanding • Aid students in interpretation of their observations, adjusting the help according to the students' level of understanding.	

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• As a conclusion of the activity the whole class reflects together on their findings and the implications for the answers to the posed math problem.	• Take part in the final reflection together with the students. • Assess students' understanding.	• Art is used as a help to visualize some abstract mathematical concepts.

6. Additional Information

The Pi-day consists of several parallel sessions:

8) An artistic activity the students should prepare in class before the Pi-day. The art assignment was to paint a mathematical concept of their own choice. The paintings are displayed in the exhibition.
9) Practical problem-solving activities in Vetenskapens Hus, inquiry based activities focusing on different mathematical concepts and tasks.
10) Lectures by researchers presenting how math is used in different disciplines.
11) An exhibition where university students inspire and inform about further studies in math, a quiz, imaginary, information about pi and historical mathematicians etc.

The Pi-day is arranged in collaboration between students and researchers from two different universities and the staff from Vetenskapens Hus.

The Pi-day is arranged at the university campus and in Vetenskapens Hus.

Problem solving activity where the pupils investigate the meaning of a *mathematical proof.*

7. Assessment

Students' understanding is assessed from the students' engagement with the activities. The staff arranging the day make an internal evaluation of the day to specify what went well and areas for improvements based on the students' engagement.

The teachers assess the activity through a questionnaire where they are asked to evaluate the scientific and pedagogical value of the whole activity as well as its connection to the Swedish school curriculum.

The CREATIONS evaluation for students is the short SMQII – questionnaire.

8. Possible Extension

Problem solving activity where the pupils investigate how math is applied in encoding and encryption.

During the day, in the exhibition part, the visiting pupils meet tutors and other young people that organize help with homework and after school activities in math available for them to use.

The Pi-day is celebrated in many places in different extent and the day in Vetenskapens Hus has grown with more activities and participating researches.

Problem solving activity where the pupils investigate different ways to represent numbers. In this activity rational numbers are represented by knots (Conways tangles)

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

TIMSS 2015 (Trends in International Mathematics and Science Study)

http://timss2015.org/

https://www.skolverket.se/om-skolverket/publikationer/visa-enskild-publikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D3707

PISA 2015 (Programme for International Student Assessment)

http://www.oecd.org/pisa/

https://www.skolverket.se/om-skolverket/publikationer/visa-enskild-publikation?_xurl_=http%3A%2F%2Fwww5.skolverket.se%2Fwtpub%2Fws%2Fskolbok%2Fwpubext%2Ftrycksak%2FRecord%3Fk%3D3725

D3.2.103 Skygazer

Project Reference:	H2020-SEAC-2014-2015/H2020-SEAC-2014-1 , 665917	**Author:**	Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH
Code:	D 3.104.	**Contributors:**	
Version & Date:	Version 1.1, 2018-02-12	**Approved by:**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Astronomy, physics, arts, language

1.2 Type of Activity

The activity is a combination of:

e) school based (an educational activity based on creativity-enriched Inquiry Based Approaches) and
f) science centre / research centre based (an educational activity that promotes school-research center collaboration)

The activity is local in Stockholm, but the school based activity can easily be extended to a national activity to be used in schools all over Sweden.

1.3 Duration

The science centre/research based activitiy: 90-120 min

The school based activity: 1-4 weeks

1.4 Setting (formal / informal learning)

The setting is both formal and informal.

The activity is introduced in an informal setting at a science centre/research centre.

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After the introductory activity the students follow up the visit and continue to do work in the classroom. They also do observations outside the classroom.

1.5 Effective Learning Environment

- Simulations
- Arts-based
- Dialogic Space / argumentation
- Experimentation (Science laboratories)
- Visits to research centers (physical)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach

2.1 Challenge

The main challenge is the lack of interest and motivation in science education in general as well as a lack of self-confidence in science. Another challenge is the poor understanding among young people about the nature of science and scientific inquiry, and their lack of knowledge about possible careers paths involving science. In this demonstrator we specifically focus on physical science in the area of astronomy. Astronomy is a very visual field that engages many young people. Beautiful pictures and fascinating objects, such as black holes, vast distances stimulate the fantasy and engage young people in creativity and art.

The benefits for the society are increased interest in science and technology, improved science literacy as well as increased science capital (Archer et al 2015), and the promotion of general skills such as problem solving and teamwork.

Great challenges in astronomy education, specifically, are the understanding of:

- Three-dimensional structures involved (Urban Eriksson 2014; Urban Eriksson et.al 2014). Three-dimensional features can be difficult and are often projected onto two-dimensional pages. By engaging in a three-dimensional model some three-dimensional structures appear more clearly.
- The actual and apparent movement of objects in the sky. The apparent celestial motion of different objects across the night sky has its origin in their actual motions in a complex way. Motions of the planets around the Sun, the Moon around the Earth, the rotation of the Earth and Sun etc. are examples of motions in the solar system that results in different observations.
- Misconceptions of astronomical phenomena and abstract concepts and notions within astronomy.

By combining astronomy and art we aim to overcome some of the above-mentioned challenges by promoting interest and motivation and visualizing astronomical phenomena and abstract concepts through art.

2.2 Added Value

In this activity the following aspects give added value to deal with the challenge described above:

- the meeting with researchers and university students, who can act as role models and inspire the pupils and increase their self-confidence as well as inform them about further studies and careers within astronomy and other sciences.
- the use of software that can simulate the night sky both at present, but also at any chosen time in the past or in the future, in order to visualize the motions of celestial objects. This gives students a feeling for diurnal and annual motions of the sky and a better understanding of concepts like day and night, seasons, phases of the moon and planets etc.
- the observations of their own, relating abstract knowledge and simulations to the real world
- the combination of art and science to visualize complex motions in the solar system as well as to get increased understanding, confidence and an ownership of their knowledge

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Skygazer activity is to increase students' interest and knowledge in science, particularly astronomy, through the means of inquiry, observations and different forms of artistic expression.

The Skygazer domain specific objectives are to:

- get students interested in science through combining astronomy and art
- increase knowledge and interest in astronomy through observations of celestial objects and inquiry based investigations of the observed objects
- increase students' self-confidence in the subjects involved

3.2 General skills objectives

In the context of Skygazer, students' general skills objectives are:

- Active participation and engagement in the presentation of astronomical motions, which develop a spirit of cooperation and teamwork. During the active participation and teamwork the students learn to fully support their hypotheses with strong scientific evidence, they also listen to each other and finally they come to a common decision together.

- Connecting science with arts. By using different forms of art to present their findings and observations of the apparent motions of celestial objects and relate that to the actual movements of the objects they will learn how to communicate scientific knowledge supported by evidence.
- Language skills. Scientific and astronomical concepts, phenomena and observations are presented and used as they discuss and present their results.
- Understanding and applying the scientific inquiry approach
- Understanding of scientific concepts and phenomena

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the Skygazer demonstrator is to increase students' interest, motivation and self-confidence in science, particularly astronomy, through the means of inquiry, observations and different forms of artistic expression. It also gives the students an increased understanding of the apparent motion of the sky as well as the origin of diurnal and annual changes of celestial objects and the three-dimensional structure of the universe.

By combining observations, simulations and art, the students learn about astronomy and the celestial motions in a creative way, and get an opportunity to discover and clarify misconceptions.

The Skygazer demonstrator also aims at developing an understanding about scientific inquiry, how to identify questions and concepts that guide scientific investigations, formulate and revise scientific explanations and models using logic and observations, and communicate and defend a scientific argument. The students also meet role models in the form of older students and young scientists who can inform them about further studies and possible career paths.

4.2 Student needs addressed

In the demonstrator students identify relevant questions (within the given framework), do observations and simulations to construct knowledge in order to improve their understanding of the actual and apparent celestial motions.

The students get introduced to the subject and software by researchers and university students, which act as role models in a university setting.

The students pose a scientific question related to the observable, celestial objects, based on their meetings and introduction by university students and their experience from the simulations.

In the classroom they do a set of observations of the sky to help them explore the question they have posed. With the help of their observations and simulations they formulate explanations based on evidence. They connect explanations to scientific knowledge and communicate with other students. This communication may be done using artistic expressions. At the end of the activity the whole class reflects together on their findings and the implications for the answers to the posed questions.

Their findings may be illustrated through any form of artistic expression. The form of artistic expression may be chosen by the students or set by the teacher. Examples of forms for the artistic expressions are acting, dancing, modelling, drawing, writing etc to understand and learn about the celestial motions. They produce an artistic representation, which they share and discuss with other students to clarify their questions and findings.

5. Learning Activities & Effective Learning Environments

Science topic: (Relevance to national curriculum) Class information Year Group: year 1 to 9 Age range: 7-16 years Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Binoculars, computers, software for simulations of the movements of celestial objects (i.e. Stellarium), material for the art workshop** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **The introduction takes place at Vetenskapens Hus/ science center/university area. The observations and art activities take place in schools. Observations of the night sky need to be done during the evenings at dark places with no streetlights.** *Health and Safety implications?* **Care should be taken if observing the Sun** *Technology?* **Computers, simulation software, binoculars** *Teacher support?* **Scaffolding**
Prior pupil knowledge **Before the visit to Vetenskapens Hus the student should be familiar with the different components of the solar system.**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Learn about the objects in the solar system and their motions

Learn about more distant observable celestial objects

Understand how to do observations of the sky

Understand how to use simulations to learn about celestial objects and their motions

Relate the observed motions to the actual motions of the objects

Assessment	**Differentiation**	**Key Concepts and Terminology**
Assessed according to the Swedish school curriculum. **Students' understanding is assessed from the students' engagement with the activities.** **The CREATIONS evaluation for the students, the Science Motivation Questionnaire for Students, the short SMQII, may be used.**	*How can the activities be adapted to the needs of individual pupils?* **The activity will be adapted for different age groups as needed to take into account variation in prior knowledge between different groups.** **The activity is available to students with disabilities.**	**Science terminology:** astronomy, geometry, physics, simulations, observations **Arts terminology:** performance, choreography, music, novel, poems, painting, sculpture

Session Objectives:

During this scenario, students will
Improve their understanding of :

- **the geometry and structure and motions of the solar system,**
- **facts about the objects in the solar system and/or other observable celestial objects**
- **how to do observations**
- **how to use simulations to achieve an understanding of the appearance of the night sky**
- **the relation between the apparent and actual movements of celestial objects**
-

Meet inspiring role models in the form of older students who guide them during the introductory activity.

Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	The question posed by the student is a result of a dialogue with university students, teacher as well as with other students. The question is based on scientific knowledge from the introduction with university students, simulations and observations of their own.	The teacher will have a dialogue with the students to clarify and structure the question, support them with the simulations and observations.	Creativity in formulating a scientific question by for example drawing, story writing, photography, etc
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk,*	The students do simple simulations with the help of for example Stellarium,	The teacher divides students into groups and guides the	Drawings or photography of the objects on the sky

	immersion and play is crucial in *empowering* pupils to generate, question and discuss evidence.	and observations of object on the sky in order to collect evidence for the posed question.	students as and when they need help The teacher identifies possible problems and misconceptions	over a period of time may be a way to collect and visualize some of the evidence
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Students engage in analysing the observation and using the simulations to interpret their results. This is done in dialogue with each other and with the teacher.	The teacher acts as a facilitator of the process. They have a dialogue with the students to be support in the analysis.	The drawings or photography of the objects on the sky can be used in the analysis.
Phase 4:	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	With the help of observations and the simulations the students formulate an	The teacher acts as a facilitator of the process.	The drawings or photography of the objects

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EXPLAIN: students formulate an explanation based on evidence		explanation to the posed question. This is done in dialogue with each other and with the teacher.		on the sky can be used in the explanation.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	The students connect their explanations from the observations to the actual motions of the objects as seen in the simulations.	The teacher encourages interdisciplinarity in explanations by pointing out connections to art and other disciplines	
Phase 6:	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of	Students communicate with each other, with the teacher and with	The teacher • assess students' understanding	Art is used as a help to visualize and communicate apparent and

COMMUNICATE: students communicate and justify explanation	the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	tutors (university students) in order to get help with their observations and simulations, as well as to communicate their experiences, analysis and evidence. Through this activity the students get an opportunity to practice the communications of scientific ideas to a varied audience, consisting of their peers, their teacher and university students.	• Aid students in interpretation of observations, adjusting the help according to the students' level of understanding.	actual motions, as well as facts about celestial objects. Examples of possible artistic activities are storytelling, dancing, pictures, sculptures.

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	As a conclusion of the activity the whole class reflects together on their findings and the implications for the answers to the posed questions. Collective ideas are generated and the solution-finding process is achieved through dialogue between different student groups and university students.	The teacher: • Take part in the final reflection together with the students. • Assess students' understanding.	The students' artwork, e.g. stories, dance, pictures etc., is used as a help to visualize and reflect on the result of the posed questions

6. Additional Information

Below follows a more detailed description of the activity which can be useful for anyone wanting to work with the demonstrator with his or her own students.

The demonstrator consists of two parts.

1. A visit to a science centre/university.
   During a hands-on activity the students get acquainted with the current night sky as well as current activities on the Sun.
   During the visit the students get to use software to investigate the sky. Examples of software are Stellarium or Skyview.
   Depending on the age of the students they either learn about the night sky (year 1-3), the solar system (year 4-6) or the universe (year 7-9)

2. An activity in the class room involving observations and art

   The students pose a question of their own choice based on their knowledge from the science centre visit, which they can investigate by observing the sky.

   The observations will take place during a period of time. Through artistic representations their findings will be presented and used in discussions.

   Examples of possible questions to work with and investigate in the classroom:

   - What did the night sky look like the day you were born? Compare it to the present night sky. What differs? Why?
   - Choose a favourite celestial body (star, planet, moon, nebula, etc). Observe it during 2 – 4 weeks at a specific time. How does its position vary with time? Why?
     Find and present facts about your favourite object.
   - Observe (by projecting it onto a piece of paper) the Sun during a period of 2-4 weeks. Are there any sunspots on the surface? Do their position and size vary over time? How and why?
   - Observe the Moon for a period of 2-4 weeks. What phases do you see? How can that be explained?

   Present your observations and findings through art. For example story telling, dance, drawing etc.

   Links to possible software:

   Stellarium: http://www.stellarium.org/sv/

   Skyview:
   https://itunes.apple.com/us/app/skyview-free-explore-the-universe/id413936865?mt=8

   https://play.google.com/store/apps/details?id=com.t11.skyviewfree&hl=sv

Links to the current night and day sky:

Star map: http://www.popularastronomi.se/stjarnkarta/

Night sky: http://www.astroinfo.se/wordpress/, http://nak.se, http://stjarnhimlen.se

Sun and aurora: http://www.spaceweather.com

Satellites and ISS: http://www.heavens-above.com

Links to astronomical news:

Astronomy picture of the Day: https://apod.nasa.gov/apod/astropix.html
Populär astronomi: http://www.popularastronomi.se

7. Assessment

Assessed according to the Swedish school curriculum in the subject of physics:

Through teaching in the subject of physics students will be given the opportunity to develop their ability to

- Carry out systematic investigations in physics, and
- Use the concepts, models and theories of physics to describe and explain physical relationships in nature and society

Central content:

Year 1-3:

Year-round in nature

• The movements of the Earth, the Sun and the Moon in relation to each other. The different phases of the moon. Constellations and the appearance of the sky at different times of the year.

• Seasonal changes in nature and how to recognize the seasons.

Methods and scientific skills

• Simple scientific studies.

• Documentation of scientific studies with text, images and other forms of expression.

Year 4-6:

Physics and our world view

- The components of the solar system and their motion in relation to each other. How day, night, months, year and season can be explained.

Methods and scientific skills

- Simple systematic surveys. Planning, execution and evaluation.

Year 7-9:

Physics and our world view

- The structure of the universe with celestial bodies, solar systems and galaxies, as well as movements and distances between them.

Methods and scientific skills

- Systematic surveys. Formulation of simple questions, planning, execution and evaluation.
- The connection between physical investigations and the development of concepts, models and theories.

The CREATIONS evaluation for the students used is the Science Motivation Questionnaire for Students. Either

- the pre-test contains questions from SMQII, questions about problem-solving, as well as a visual test. The post-test contains questions from SMQII, questions about problem-solving, Intrinsic Motivation Questionnaire, and a visual test, or
- the short SMQII – questionnaire both as pre- and post-test.

8. Possible Extension

The activity can be extended to a full-year activity in the class-room, where observations of the sky at different seasons are combined to improve the student's understanding of astronomy and the motion of objects in space.

As a part of a more prolonged activity the class can take part in the activity Astronomy Day and Night (described in the demonstrator KTH-3.1_Demonstrators_ADON)..

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Säljö, Roger (2000). *Lärande i praktiken: Ett sociokulturellt perspektiv*. Stockholm: Norstedts Akademiska Förlag.

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D3.2.104 Stockholm Master classes in particle physics

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH**
Code:	D 3.2.104.	**Contributors:**	
Version & Date:	Version 1.2, 2018-02-06	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Particle physics

1.2 Type of Activity

The activity is science centre / research centre based

The activity is local in Stockholm. It is a part of the International Masterclasses – hands on particle physics arranged by IPPOG.

The day consists of lectures by researchers, hands-on activities, analyse of particle data, meeting with scientists from the universities, discussions and problem solving.

1.3 Duration

1 day

1.4 Setting (formal / informal learning)

The setting is both formal and informal.

The activity takes place in an informal setting in a Science centre and university setting.

1.5 Effective Learning Environment

- Communities of practice (physical)
- Simulations
- Dialogic space / argumentation
- Arts based
- Experimentation (Science laboratories and eScience applications)

CREATIONS has received funding from the European Commission HORIZON2020 Programme

- Visits to science centre (physical and virtual)
- Communication of scientific ideas to audience

2. Rational of the Activity / Educational Approach - ok

2.1 Challenge

One of the main challenges in education today is the lack of interest in science education, and the need to promote motivation for the physical sciences. Another important challenge is the need to promote 21st century skills in the classroom, such as problem solving, analytical reasoning and teamwork. Particle physics is an inspiring area, which fascinates young people, and can therefore be used as a mean to promote curiosity and a desire to learn more as well as 21st century skills. However, it is also a subject where the knowledge advances with new discoveries, and in which many teachers experience that they lack competence. Particle physics is a very abstract area which involves phenomena that cannot be directly observed, and which therefore includes a lot of modelling. This makes it difficult for students to grasp the theory and to see the connection to reality. In order to facilitate the students' understanding a combination of art and science can be used, where images of different kinds are utilized to visualize particles and interactions.

Challenges in particle physics are the understanding of:

- Standard model of particle physics
- How particles may be detected and observed
- The connection between theory and experiments
- The limits and error sources in in the experimental settings
- The generation of particles in particle accelerators as compared to cosmic particles

2.2 Added Value

The purpose of the demonstrator is to let students, in their last year of upper secondary school, as well as teachers meet scientists and university students in particle physics both at the university and during virtual meetings with scientists at CERN. The meeting with university students and scientists will engage the students in discussions and encourage them to collaborate with the purpose to increase their interest and understanding in fundamental physics. By letting the students analyse real particle data they will get a feeling for the work of a scientist in the area, and the relation between theory and experiments.

The data analysed is from the ATLAS-detector at the Large Hadron Collider in CERN, and the software used for the analyse is HYPATIA. The students search for the Z-boson in the data sample.

In order to facilitate the students' understanding a combination of art and science can be used, where images of different kinds are utilized to visualize particles and interactions. The students' benefit from this approach is an improved understanding of abstract concepts and interactions through a combination of theoretical and analytical thinking and more artistic visualization.

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In Sweden there is an (optional) advanced physics course in upper secondary school where the students may immerse themselves in a specific area. The Masterclasses may be a part of the curriculum for this course.

3. Learning Objectives

3.1 Domain specific objectives

The main aim of the Stockholm Masterclasses in Particle Physics activity is to increase students' interest and knowledge in science, particularly in particle physics by letting them meet current research in the field.

The domain specific objectives are to:

- get students interested in science through meetings with scientist and university students, and practical work with real particle data
- increase the knowledge in the theory of particle physics by lectures and hands-on activities
- increase the knowledge in the experimental work and analysis of data
- initiate discussions in the field
- initiate contact between students and young scientists
- increase students' self-confidence in the subjects involved

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop understandings about scientific inquiry
- identify questions and concepts that guide scientific investigations
- formulate and revise scientific explanations and models using logic and evidence
- express notions and concepts in different ways, using physical language, mathematical symbols as well as images and artwork
- communicate their ideas
- communicate and defend a scientific argument
- meet role models in the form of older students and young scientists

3.2 General skills objectives

In the context of the Masterclasses, students' general skills objectives are:

- Active participation and engagement in the hands-on activities and experiments
- Understanding and applying the scientific inquiry approach
- Connecting theory and experiments in scientific work
- Developing a spirit of cooperation and teamwork
- Scientific interconnection of science with aspects of art

The Stockholm Masterclasses in particle physics also address a number of RRI action points: engagement, science education, gender equality (female tutors guide the students during the day and act as role models), open access.

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The demonstrator's main aim is to improve students' understanding of the standard model of particle physics and insight in fundamentals of matter and forces, enabling the students to perform measurements on real data from particle physics experiments. By improving understanding and knowledge of the theory and experiments, we aim to increase students' confidence and interest for science in general and particle physics in particular.

4.2 Student needs addressed

In the demonstrator students identify relevant questions (within the given framework), investigate, experiment and analyse data to construct knowledge in order to improve their understanding of particle physics. This will give the students the opportunity to improve their skills in problem solving, analysis and teamwork.

The IBSE approach in connection with the access to real particle data and software makes the knowledge relevant to the students with the purpose of increasing their, and their teachers' self-confidence, as well as promoting the students' problem-solving ability, analytical thinking and teamwork.

The CREATION features and RRI aspects are addressed and applied both in the lectures, the meetings with university students and researchers, in the hands-on activities as well as in the data analyse. Men dominate research in particle physics. By involving female role-models we want to show the girls that this is a relevant area also for them to pursue their studies within. Through the use of dialogue and collaboration the students will exercise their communicative skills and through discussion with their peers and teachers will engage in analysis and problem-solving leading to an improved understanding and increased interest.

5. Learning Activities & Effective Learning Environments

Science topic: Particle physics (Relevance to national curriculum) Swedish upper secondary school curriculum Class information Year Group: 12th grade (upper secondary school) Age range: 18-19 years Sex: Both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need?* **Equipment: cloud chamber, cosmic rays detectors, e/m apparatus** **Computers with internet access. Video equipment to connect to CERN and the other participating universities** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Preparatory and follow-up activities (optional) take place in schools. The main activities take at Vetenskapens Hus in Stockholm and at research groups at the universities.** *Health and Safety implications?* **No** *Technology?* **Computers with internet access.** **Video equipment.** *Teacher support?* **Scaffolding. Teacher material is available at website.**
Prior pupil knowledge **General physics and mathematics corresponding to the last year of upper secondary school, science and/or technology program. No prior knowledge in particle physics is required.**	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)* During this scenario, students will ▪ have lectures (learn the basic theory in particle physics and meet researchers) ▪ do hands-on activities (meet university students which act as role models, experiments that illustrate the theory) ▪ analyse real particle physics data (get an understanding of the work done by a researcher) ▪ visit research groups in particle physics at the university (meet researcher and learn about current research in the field) ▪ connect, by video, to researchers at CERN and to 4 other universities in Europe (meet researcher and get an understanding about the need of collaboration)		
Assessment **Student groups will present their analysis and discuss with other groups to arrive at a conclusion concerning the types of particle interactions involved. Student engagement and questions asked during the activities and during final video conference with CERN will give an indication of their understanding and how inspired they become.**	**Differentiation** *How can the activities be adapted to the needs of individual pupils?* **No prior knowledge in particle physics is required. The theory and analyse tool is introduced during the day. There are researcher and university students guiding the students and answering and clarifying questions during the day.** **The activity is available to students with disabilities.**	**Key Concepts and Terminology** **Science terminology:** Particle physics, standard model, radiation, cosmic rays, accelerator, detectors. **Arts terminology:** Images, visualization

Session Objectives:

During this scenario, students will
Increase their understanding of fundamental physics, particles and forces and the way researcher investigate theoretical questions related to the area by detecting and analysing data.
Meet inspiring role models in the form of older students who guide them during the activities.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental	• Students will meet university students and researcher creating dialogues between students-university student, students –	• Will also take part in the activities and have a dialogue with the students to clarify and structure the question.	• Potential art activities are the use of photography during the day as well as work with illustrations

	design and collaborative work, as well as in the initial choice of question.	researchers, students-teachers, students-students		and images connected to the data analysis.
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• Students will analyse real data from the ATLAS detector at LHC, CERN	• The teachers take part in the analysis and the other activities during the day. • Teachers discuss with and guide students.	Students will use visualizations as an aid to investigate interactions and use this as evidence to support their interpretations.
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	• Students engage in analysing data and interpreting what they observe	• Acts as a facilitator of the process. Takes active part in the analysis and discuss with students.	Students use visualizations as a tool to analyse the data.

Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	• Based on the analysis of the data the students determine the mass of the Z-boson and identify the Higgs boson.	• Acts as a facilitator of the process and take active part in the activity.	Images and visualizations act as a base for formulating explanations.
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	• The students use the knowledge from the lectures and the data analysis to reflect on, and question current ideas in particle physics.	• Take part in the discussions and reflections together with the students.	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	• Students communicate with each other and with tutors (university students) in	• Aid students in interpretation of analysis, adjusting the help according to the students' level of understanding.	Using images the students communicate their results within and between student teams.

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		order to get help with their analysis and understanding • Students communicate and compare their results in a final video conference with CERN and 4 other universities.	Support them during the final vidoe conference.	
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• As a conclusion of the activity all students reflects together on their findings during the	• Take part in the final reflection and quiz	• Images may be used as a help to visualize and reflect on the results.

		video conference. The students also take part in a quiz.	together with the students.	

6. Additional Information

The activity is taking part for a full day.

Agenda for the day:

9:00 – 9:05 Welcome!

9.10 – 9:50 Lecture: "The Standard model in particle"

9:50 – 10:00 Break

10:00 – 10:45 Experiments and demonstrations in Vetenskapens Hus:

- weighing the electron in our "particle accelerator",
- examining traces of particles in our cloud chamber,
- demonstration of a myon detector

10:45 – 11:15 Lecture: "LHC and ATLAS"

11:15 – 12:15 Lunch

12:15 – 13:00 Introduction to the analysis: "To study decays in ATLAS"

13:00 – 14:30 Analysis of particle collisions in the ATLSA detector in LHC.

14:40 – 15:20 A visit to research group at the university.

15:30 – 16:00 Summary of results

16:00 – 17:00 Video conference with CERN and 4 other European universities.

Hypatia is the software used for the analysis.

Relevant links:

International Masterclasses: http://physicsmasterclasses.org

http://physicsmasterclasses.org/index.php?cat=country&page=se

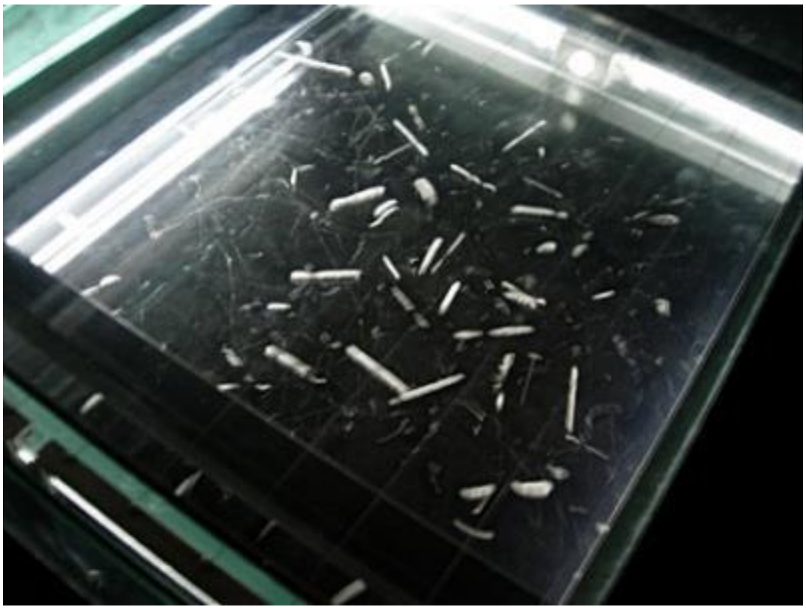
http://physicsmasterclasses.org/index.php?cat=country&page=se_stockholm2

Hands-on-CERN: http://www.physicsmasterclasses.org/exercises/hands-on-cern/hoc_v21en/

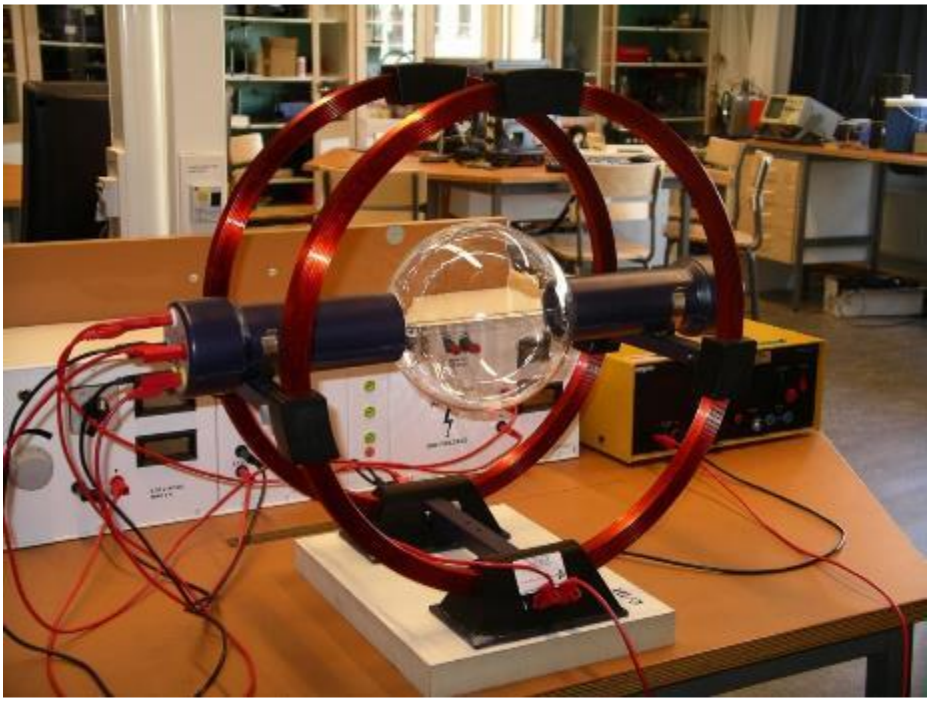
Hypatia: http://hypatia.phys.uoa.gr

http://atlas.physicsmasterclasses.org/en/zpath_teilchenid2.htm

Detection of myons that form at the top of our atmosphere.



Our cloud chamber where we observere traces of charged particle.



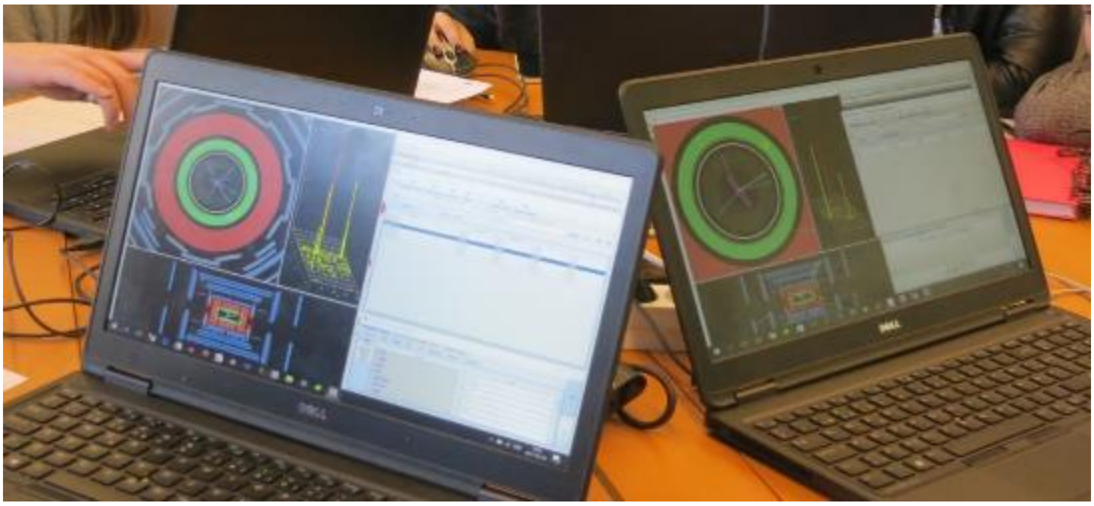
Our "particle accelerator" where we weigh the electron.

7. Assessment

Assessed according to the Swedish school curriculum for upper secondary school:

The teaching in the subject of science specialization will give students the opportunity to develop the following:

- Knowledge of relevant concepts, models, theories and working methods and understanding of how these develop.
- Ability to analyze and seek answers to topic-related questions as well as to identify, formulate and solve problems.
- Ability to reflect on and evaluate selected strategies, methods and results.
- Ability to plan, implement, interpret and report investigative work as well as ability to handle materials and equipment.
- Ability to use knowledge in science to communicate as well as to review and use information.



Students and teachers take an interactive quiz at the end of the day, during the video conference.

HYPATIA is used to analyse particle collisions from the ATLAS-detector, LHC, at CERN.

CREATIONS evaluation for the students.

8. Possible Extension

The activity can be extended to an activity in a school setting after the Masterclasses, as a part of an advanced physics course in upper secondary school.

It is possible for the students to download the software for analysing data (HYPATIA) and access particle physics data from the ATLAS-detector. They can explore ATLAS and LHC on their own (https://www.higgshunters.org/).

The Masterclasses can also be extended to further include artistic expressions such as for example:

- photography during the day, activities in the classroom afterwards such as story-telling or work with illustrations connected to the data analysis,
- art (ex. photography, painting) as a help to visualize and reflect on the results.

9. References

Barnett R M and Johansson K E, 2006, *The education and outreach project of ATLAS—a new participant in physics education,* Phys. Educ*.* **41** 432

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Barnett R M, Johansson K E, Kourkoumelis C, Long L, Pequenao J, Reimers C and Watkins P, 2012, *Learning with the ATLAS experiment*, Phys. Educ. **47** 28

Johansson K E and Watkins P M, 2013, *Exploring the standard model of particles,* Phys. Educ. **48** 105

Johansson K E, 2013, *Exploring quarks, gluons and the Higgs boson,* Phys. Educ. **48** 96

http://atlas.cern

www.cern.ch

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http://physicsmasterclasses.org/index.php?cat=country&page=se_stockholm2

http://www.physicsmasterclasses.org/exercises/hands-on-cern/hoc_v21en/

http://hypatia.phys.uoa.gr

http://atlas.physicsmasterclasses.org/en/zpath_teilchenid2.htm

https://www.higgshunters.org/

https://cernatschool.web.cern.ch/

D3.2.105 Technology Eight 2017 Stockholm – class project

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	**Cecilia Kozma, Tanja Nymark, Vetenskapens Hus, KTH**
Code:	D 3.2.105.	**Contributors:**	
Version & Date:	Version 1.4, 2018-02-06	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

technology, engineering, design, arts, language

1.2 Type of Activity

The activity is a combination of:

g) School based and
h) Science centre / research centre based activity that promote school-research center collaboration

The activity is local in Stockholm, but is part of a large national activity in Sweden.

1.3 Duration

4-6 weeks preparation in school

1 day at research centre / university

1.4 Setting (formal / informal learning)

The setting is both formal and informal. The activity involves preparation in the classroom, while the presentation takes place in an informal setting. There initial competition, which is a quiz, takes place in the classroom. The quarterfinal and the regional final competition will take place in a science centre and university.

Formal and informal learning settings

- Classroom
- Science centres
- Research centre / university

1.5 Effective Learning Environment

- Communities of practice (physical)
- Dialogic space / argumentation
- Arts-based
- Experimentation (classroom)
- Visits to research centre (physical)
- Communication of scientific ideas to audience (blog + physical)

2. Rational of the Activity / Educational Approach

2.1 Challenge

The interest among young people for careers in engineering has been dwindling for the past decades. Although young people in Sweden generally show a great interest in the newest technological gadgets they do not appear to see technology and engineering as future career opportunities for themselves. The purpose of this demonstrator is to involve students in a practical project which combines technical development with arts and design in order to improve student understanding of the different aspects of engineering and innovation, and increase their feeling of self-efficacy in these subjects.

A challenge is also to prepare and train young people in general skills, such as problem solving and teamwork, needed for the 21st century

2.2 Added Value

The Technology Eight ("Teknikåttan" in Swedish) is a nationwide tournament for students in grade 8 (ages 14-15). The competition is organized by 11 technical universities. KTH/The House of Science are responsible for the Stockholm region.

The tournament consists of several steps, starting with an initial quiz where about 25000 students all over Sweden participate. Among these a number of school classes are selected to go on to the next round of the tournament which is organized at each participating university. The classes that take part in the regional competitions are given a practical project to work with in school. This project consists of a practical and technical challenge, which they prepare in advance and present at the beginning of the regional finals. This task involves the whole class and necessitates smart technical solutions, creativity and collaboration. The 2017 challenge is to construct a terrain vehicle which should fullfill certain requirements defined in the instructions, and to be able to pass through a number of obstacles.

In the Stockholm region the classes taking part in the regional tournament are selected in an inital competition which takes place at the House of Science in March. 18 classes are invited to this event. From these 18 classes we select 6 classes that are invited to go on to the next round. These 6 classes are given the practical challenge, and will have 6 weeks to prepare it before the regional finals at the end of April.

The practical and technical task which they work with in school requires collaboration and creativity. It involves students in a practical project which combines technical development with arts and design in order to improve student understanding of the different aspects of engineering and innovation, and increase their

feeling of self-efficacy in these subjects. During the competition, that takes place in Science centres and universities, the students meet young scientist which act as role models.

3. Learning objectives

3.1 Domain specific objectives

The T8 domain specific objectives are to:

- get students interested in technology and engineering through practical construction work.
- give students an understanding of the connection between art and technological design by encouraging artistic expression as part of the construction work.
- inspire students through visits to research laboratories.
- increase students' self-confidence in technological development.
- initiate contact between students and professionals.

Towards attaining these objectives, peripheral aims are formed addressing students' needs to:

- develop understanding about technological development and engineering.
- identify questions and concepts that guide technological development.
- formulate and revise technical solutions using logic, testing and evidence.
- communicate and defend choices of technical solutions.
- compare their technical solutions to those of other student groups.
- meet role models in the form of older students and young scientists.

3.2 General skills objectives

In the context of the T8 class project, students' general skills objectives are:

- Active participation and engagement in the development of technical constructions develop a spirit of cooperation and teamwork. During the active participation and teamwork the students learn to support their hypotheses and constructions with scientific evidence, they listen to each other and finally they decide on a common construction together.
- By solving the task the students learn to apply technological know-how and creativity to solve problems. As a part of the task is to design the vehicle they also include esthetical aspects and connect technology with arts.
- Language skills are practiced both in the collaborative work and when their vehicle is presented at the competition. During the construction project they also document their work.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

The main aim of the "Technology Eight 2017 Stockholm – class project" (T8) activity is to increase students' interest and self-efficacy in technology and science and their understanding of the importance of creativity for problem-solving.

The Technology Eight (”Teknikåttan” in Swedish) is a nationwide tournament for students in grade 8 (ages 14-15) and is organized jointly by 11 Swedish technical universities. The classes that take part in the regional competitions are given a practical project to work with in school. This project consists of a practical and technical challenge, which they prepare in advance and present at the beginning of the regional finals.

The practical and technical challenge requires collaboration and creativity. It involves students in a practical project which combines technical development with arts and design in order to improve student understanding of the different aspects of engineering and innovation, and increase their feeling of self-efficacy in these subjects. During the competition, that takes place in Science centres and universities, the students meet young scientist which act as role models.

4.2 Student needs addressed

The students are given a theme for a practical task to develop. Through collaboration and dialogue the students identify relevant solutions to the given task. A vehicle is designed and tested. The students engage in analysing the results and how to improve the task. With the help of observations and discussions students choose the best possible design for the construction. Students communicate with each other and with their teacher The students describe the whole process in a blog, where they analyse all test results and reflect on their choices and final design.

A part of the task is also to consider the esthetical appeal of the vehicle, and a prize is also awarded for the best design both in terms of function and of visual appearance.

5. Learning Activities & Effective Learning Environments

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: Technology, physics, engineering (Relevance to national curriculum) Swedish middle school curriculum Class information Year Group: 8th grade (middle school) Age range: 14-15 years Sex: Both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need?* **Material to build the obstacle course** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* **Preparatory activities take place in schools. The presentation of the project takes place at the Royal Institute of Technology (KTH) in Stockholm.** *Health and Safety implications?* **None** *Technology?* **Camera, timer** *Teacher support?* **Scaffolding**
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will improve their engineering skills and their feeling for the connection between arts and engineering when designing a vehicle. They will get an improved self-confidence and problem-solving ability.

Assessment	**Differentiation**	**Key Concepts and Terminology**
The project will be assessed through a competition between the participating school classes. **Student engagement during the activity will give an indication of their understanding and how inspired they become.**	*How can the activities be adapted to the needs of individual pupils?* **The activity is available to students with disabilities.**	**Science terminology:** Technology, physics, engineering **Arts terminology:** Design

Session Objectives:

During this scenario, students will
Gain an improved understanding of technological work and design.
Get an increased feeling of self-confidence in engineering and technological development.
Develop a spirit of cooperation and team-work.
Meet inspiring role models in the form of older students who guide them during the activity.

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an	• Is given a theme for a practical task to develop	• Will have a dialogue with the students to clarify and structure the work on the project	•

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	important consideration in experimental design and collaborative work, as well as in the initial choice of question.			
Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	• Test different designs for the construction and document the performance of each design • Discuss within and between students groups to assess different test results in order to decide on the best possible construction	• The teacher divides students into groups and guides the students as and when they need help	

Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	• Students engage in the analysing the performance of different designs by interpreting what they observe	• Acts as a facilitator of the process	
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	• With the help of observations and discussion students choose the best possible design for the construction	• Acts as a facilitator of the process	•
Phase 5: **CONNECT:** students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of	• Students document their tests and final results and explain the choices of the	• Encourages interdisciplinarity in explanations by pointing out connections to	•

	their evidence and explanations in relation to the original question.	final design based on test results	art and other disciplines	
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	• Students communicate with each other and with their teacher in order to get help with their practical work • Students communicate their work through a blog which is openly available	• Assess students' work • Aid students in interpretation of test results, adjusting the help according to the students' level of understanding.	

Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	• Students describe the whole process in a blog, where they analyse all test results and reflect on their choices and	• Assess students' understanding.	

6. Additional Information

7. Assessment

The constructions are assessed by their function during the presentation.

The change in the students' understanding during the project can be assessed through their blog, where they continuously describe their work, their ideas, tests, results and choices that are made based on test results.

The students' interest and self-confidence are assessed by the their engagement in the presentation.

The teachers assess the activity through a questionnaire where they are asked to evaluate the scientific and pedagogical value of the whole activity as well as its connection to the Swedish school curriculum.

Task:

A terrain vehicle must pass through a given obstacle track and stop within a target area. Maximum time from start until the vehicle is stationary in the target area is 60 seconds. A ready-made obstacle course is available in the competition hall. The task is to construct and build a terrain vehicle. The vehicle may consist of manufactured components, such as axles and wheels, or may be completely self-manufactured. However, the vehicle may not be powered or controlled by electricity, pyrotechnics, internal combustion engines or live animals.

Assessment of the task:

The rating is made when the vehicle has stopped completely or 60 seconds after the start signal.

2p (points) if the entire vehicle passes the first obstacle and touches the bottom of the track between the first and second obstacle

+ 2p if the entire vehicle passes the second obstacle and touches the bottom of the track between the second and third obstacle

+ 2p if the entire vehicle passes the third obstacle and touches the bottom of the track between the third and fourth obstacles

+ 2p if the entire vehicle passes the finish line and touches the bottom of the track in the target area

+ 2p if the entire vehicle stays within the target area

+ 2p for the vehicle closest to the goal line, measured from the rear of the vehicle, provided that the entire vehicle has remained within the target area

+ 1p if a logbook was written and available as a blog on the internet.

+ 1p if the logbook contains all parts as described in the instruction (see below).

Instructions for the logbook (blog)

During the course of the work, the class will keep a logbook in the form of a blog documenting the work on the task.

The blog should contain:

1. name of class and school
2. an introductory text explaining the task you are going to solve
3. text and sketches / photos / films describing the different phases of the work, for example:

   - suggestions for a solution, preferably several suggestions
   - construction and building, continuous work
   - successful / failed tests

In order to achieve full marks, the blog should be available on T8:s website from March 31, 2017. The blog should be updated during the course of work and be completed on April 25, 2017.

Design award

The best-designed terrain vehicle will be awarded with a special design prize.

CREATIONS evaluation

The CREATIONS evaluation for the students used is the Science Motivation Questionnaire. Either

- the pre-test contain questions from SMQII, questions about problem-solving, as well as a visual test. The post-test contain questions from SMQII, questions about problem-solving, Intrinsic Motivation Questionnaire, and a visual test, or
- the short SMQII – questionnaire both as pre- and post-test.

Link to the pre-test: https://goo.gl/forms/5wMv76wFtbGOJo7G2

Link to the post-test: https://goo.gl/forms/ONDQSBFIkV72tKcj2

8. Possible Extension

The activity can be extended to a national or even international event. It can also easily be extended to other age groups. This and previous class projects are freely available on the open website "Kunskapsnätet".

The activity can be adapted by teachers as a longer project in the classroom that focuses on different parts of the curriculum. It can also be used as a collaborative project within a school, with competition between different classes.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

9. References

Relevant links:

http://www.teknikattan.se

http://www.kunskapsnatet.nu

http://www.vetenskapenshus.se/teknikåttan

D3.2.106 Science Talks

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author:**	Jorge Rivero, David Lee
Code:	D 3.106.	**Contributors:**	
Version & Date:	**10/6/2016**	**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Physics, Quantum Electronics and Optics, Photonics

1.2 Type of Activity

Participative Colloquium with presentations and interactive discussion

School based (upper secondary and university)

Professional development of students, and entrepreneurs

1.3 Duration

120 – 150 minutes

1.4 Setting (formal / informal learning)

Formal or informal

- University auditoriums
- Lecture theatres
- City Halls

1.5 Effective Learning Environment

Communication of scientific ideas to an audience. The concept is a combination of a series of short, inspirational talks representing different areas of photonics applications to the students followed by a discussion where students can analyse, reflect and communicate ideas with their peers.

2. Rational of the Activity / Educational Approach

To create awareness among the students about the potential of photonics thereby encouraging them to consider Photonics as a career choice.

2.1 Challenge

To engage in a constructive dialogue between specialists in the field of optics and photonics and students;

To present the exciting research and career opportunities in optics and phonics

To convince talented individuals to follow careers in optics and photonics

2.2 Added Value

It is important to avoid technical talks. Visual aids can be useful in demonstrating:

- Why is photonics interesting?
- How does photonics impact society through what I do?
- Potential of photonics for jobs
- Passion for photonics as a career path
- Economic impact of photonics
- Alternative careers

3. Learning Objectives

To create awareness among the students about the potential of photonics thereby encouraging them to consider Photonics as a career choice.

3.1 Domain specific objectives

The session will contain a series of talks and interactive discussions with successful professionals representing different career options within photonics.

The session will focus on:

- Exposing students to the potential of careers in Photonics
- Revealing non-traditional career paths in Photonics
- Uncover the ubiquity of Photonics across disciplines

3.2 General skills objectives

Extract most important ideas from a presentation

Reflect on applications of the photonics technologies presented on the subject of their studies

Enhance collaborative skills to work in groups

Improve communications skills to present conclusions to other students

4. Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

To present the various opportunities in optics and photonics for interesting and exciting careers for students. To present that photonics technologies can be applied to many fields.

4.2 Student needs addressed

To link the career development opportunities in optics and photonics to the educational paths proposed in universities. To learn that photonics technologies could have important applications on the fields related to their studies and future careers.

5. Learning Activities & Effective Learning Environments

During lectures, in suitable auditoria, specialists present the latest research in the field of photonics.

The setting can be at schools, universities, private companies, etc.

Stimulating presentations, using the beauty of the research in photonics, as well as exciting opportunities for career development and innovation are presented using multi-media techniques (presentations, video, posters).

Ample time is allotted for extensive questions and answers.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

Science topic: Physics, Quantum electronics and optics, photonics **(Relevance to national curriculum)** **Class information** **Year Group: undergraduate, and graduate students in university** **Age range: 18-27** **Sex: both** **Pupil Ability: university studies in science and engineering**	**Materials and Resources** **Projector and computer to upload speakers' audio-visual material** **Microphones depending on the number of speakers** **Recording Devices** **Streaming facilities** ***Where will the learning take place?*** ***Health and Safety implications? none*** ***Technology?*** ***Teacher support?***
Prior pupil knowledge **university studies in science and engineering**	
Individual session project objectives ***(What do you want pupils to know and understand by the end of the lesson?)*** **Students will be introduced to wide variety of research and career challenges in optics and photonics:** • **Why is photonics interesting?** • **How does photonics impact society through what I do?** • **Potential of photonics for jobs** • **Passion for photonics as a career path** • **Economic impact of photonics** • **Alternative careers** • **Appreciation of the creativity in research, in particular in photonics** • **Use of different lighting techniques (incandescent, led etc) and impact on perception of colours**	

Assessment **Recorded material of the event** **Questionaires filled by the participants** **A brief report on the overall response of the participants indicating the number of total participants, invited speakers, topics of the talk, highlights of the event etc.**	**Differentiation** *Each session will be different, based on the local environment, the speakers invited, and the level of the students attending.*	**Key Concepts and Terminology** Optics, photonics, career choice and development **Science terminology:** Physics, optics, photonics, informatics, innovation **Arts terminology:** Creativity, light spectrum, colour, density

Session Objectives: To create awareness among the students about the potential of photonics thereby encouraging them to consider Photonics as a career choice

Learning activities in terms of CREATIONS Approach

IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION: students investigate a scientifically oriented question**	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Eg. Engage with teacher's questions. Watch videos and use the web to explore evolution.	Eg. Will use challenging questions and the web (images, videos) to attract the students' interest in ….	

Phase 2: EVIDENCE: students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Eg. Student will be curious about potential of photonics from the presentation performed by teacher/researcher	Eg. Will use experience from its professional activity to show potential of photonics	
Phase 3: ANALYSE: students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.	Eg. In different groups students analyse the information received	Eg. Teachers supervise the different groups and try to orientate the discussions	
Phase 4: EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	Eg. Students confront the information received with their scientific knowledge	Eg. Teachers supervise the different groups and try to orientate the discussions	
Phase 5: **CONNECT: students connect explanations to scientific knowledge**	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	.Eg. Students try to relate the information received with their prior knowledge on the fields they are studying	Eg. Teachers supervise the different groups and try to orientate the discussions	
Phase 6: **COMMUNICATE: students communicate and justify explanation**	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.	Eg. Students communicate their conclusions to the other groups and discuss their findings	Eg. Teachers moderate the discussions	

Phase 7: **REFLECT: students reflect on the inquiry process and their learning**	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.	Eg. Students reflect on the open questions that have been generated by the expositions of different groups	Eg. Teachers moderate the discussions	

6. Additional Information

7. Assessment

The main tool for recording assessments will be a questionnaire filled by the participants and recorded material of the event.

A brief report on the overall response of the participants indicating the number of total participants, invited speakers, topics of the talk, highlights of the event etc could be prepared with this information.

8. Possible Extension

A library of presentations for online viewing

Create a community of presenters in the field of photonics

Include career and entrepreneurial LIGHTTALKS in conferences and meetings

Propose LIGHTTALKS to science museums, and for public lectures at universities

9. References

CREATIONS Developing an Engaging Science Classroom	D.3.2 CREATIONS Demonstrators

D3.2.107 Water in art and science

Project Reference:	H2020-SEAC-2014-1 , 665917	**Author: Carole Ecoffet**	
Code:	D 3.2.107.	**Contributors:**	
Version & Date:		**Approved by:NKUA**	

1. Introduction / Demonstrator Identity

1.1 Subject Domain

Science ; visual art

1.2 Type of Activity

Artistic works based on experiments on water

1.3 Duration

4 months

1.4 Setting (formal / informal learning)

Formal learning

1.5 Effective Learning Environment

2. Rational of the Activity / Educational Approach

2.1 Challenge

Water is studied from the first years at school. States changes, properties of liquids, floating objects are widely studied in science classroom. Interdisciplinay approach is also proposed in the curriculum by studing environnemental aspects.

We can also noticed that most of the children are fascinated by all the forms of water : rain drops on windows, ice figures, snow, reflections on puddle, bubbles, etc.. But in the formal education all theses phenomena are let on the side and not studied during the science curriculum.

The sensitive and intuitive approach of water is, by the way, let at the side of the classroom. But at university and in the laboratories, all these phenomena are still topics of high level research (hydrodynamics, condensation dynamics of cold surfaces, waves, vortex, ..) and most of the students at that level do not even try to make connections between their observations and the knowledges they learn in science classroom.

The aim of this demonstrator is to propose activities adapted to the curriculum and that will connect rational and sensitive approach through observations and production of artistic pieces.

2.2 Added Value

As natural phenomena related to water fascinate students as well as grown-up, their observation is a very engaging activity. Unfortunately, most of the experiments proposed in the calls room are mostly curriculum oriented and let beside aesthetic and poetical approach. It this demonstrator, we will propose to use experimental studies on water in artworks projects.

3. Learning Objectives

3.1 Domain specific objectives

Some knowledge can be clearly used and integer in the science curriculum whereras other are still open question for researchers. However, even if all the knowledge necessary to understand natural phenomena are not in the curriculum, one can propose obervation and assesments proposal. Research is not based on the observation of the only phenomenae we already understand, but also on open questions. An art project can use this phenomena, even if

3.2 General skills objectives

In the context of EBSI, some skills may be common to art and science. This is mainly the case of observation.

Observation step has to be carefully prepared to let the students notice details, even if these will not be pertinent for scientific curriculum. This skill is diffrent of the guessing game in which there is one good answer. Students have to feel free to express really what they can see and not not only what the

4. Demonstrator characteristics and Needs of Students

3.3 Aim of the demonstrator

In this demonstrator we rpopose to take scientific experiment on water as a object for artistical works. Teachers can choose the adequate experiment realted to their curriculum and/ or to their artistic practices. Observation step, usually develloped in an science oriented manner will be also the starting point of the artistic project.

3.4 Student needs addressed

The ability of make open observation is often blocked by the disciplinary consciousness. Students try to guess what the teacher wants as an answer. But real observation has to be broader, and by considering that the experiment can also be observed for another purpose than just science course, the students will be more eager to give really all the details they can notice.

CREATIONS has received funding from the European Commission HORIZON2020 Programme

5. Learning Activities & Effective Learning Environments

This demonstrator can be adpated to different levels. The best age is between 9 and 11. At that step disciplinary counsciousness starts to appear. Possibility to show artistic production outside of the classroom in an advantage. Artistic production can also be used as support to present science to external public (scientific or artistic exhibition).

Science topic: (Relevance to national curriculum) Class information Year Group: 8 Age range: 8- 13 Sex: both Pupil Ability: eg (The scenario allows space for pupils of various abilities to participate)	Materials and Resources *What do you need? (eg.*printed questionnaires, teleconference, etc.) **Experimental science material.. as for as IBSE session.** **Art material** *Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?* Science classroom and art classroom *Health and Safety implications? none* *Technology? none* *Teacher support? Information on IBSE experiments . Links with ressource website (viaeduc in french) and with art center. Conference on art and science.*
Prior pupil knowledge	

Individual session project objectives *(What do you want pupils to know and understand by the end of the lesson?)*

During this scenario, students will

Step 1 built and observe an experiment related to water. As many observations as possible have to be written and carefully kept for science and for art project

Step 2 Go on with science IBSE session.

Step 3 Art course, propose an art work related to the experiment.

Later .. exhibition if possible , or presentation to another group.

Assessment	**Differentiation**	**Key Concepts and Terminology**
Ability to understand different levels of the reality in the experiment. To be able to follow an inquiry based protocol and to keep.	*How can the activities be adapted to the needs of individual pupils?* This project is flexible and interdisciplinary by nature and as such speaks well to a diverse group of students.	**Science terminology:** State of the matter, condensation, evaportion, ice formation, homogeneous, hétérogeneous, transparent, decantation, solid, liquid, gaz **Arts terminology:** If possible, try to use precise scientific words to also express ideas in art (for example homogeneous/ hétérogeneous..)

Session Objectives:

During this scenario, students will				
Learning activities in terms of CREATIONS Approach				
IBSE Activity	**Interaction with CREATIONs Features**	**Student**	**Teacher**	**Potential arts activity**
Phase 1: **QUESTION:** students investigate a scientifically oriented question	Students pose, select, or are given a scientifically oriented question to investigate. *Balance and navigation* through *dialogue* aids teachers and students in creatively navigating educational tensions, including between open and structured approaches to IBSE. Questions may arise through *dialogue* between students' scientific knowledge and the scientific knowledge of professional scientists and science educators, or through *dialogue* with different ways of knowledge inspired by *interdisciplinarity* and personal, embodied learning. *Ethics and trusteeship* is an important consideration in experimental design and collaborative work, as well as in the initial choice of question.	Experimental set-up proposed are related to the science curriculum	Experimental set-up proposed are related to the science curriculum	Freedom in the expression of the observation of natural phenomena related to water.

Phase 2: **EVIDENCE:** students give priority to evidence	Students determine or are guided to evidence/data, which may come from *individual, collaborative and communal activity* such as practical work, or from sources such as data from professional scientific activity or from other contexts. *Risk, immersion and play* is crucial in *empowering* pupils to generate, question and discuss evidence.	Students will have to test and to observe water phenomena. Groups of 3 to 4 are ok to allow dialogue on observation; Notes have to be taken individually	Teacher help them to formulate observations	Keep all the observations to start an art project
Phase 3: **ANALYSE:** students analyse evidence	Students analyse evidence, using *dialogue* with each other and the teacher to support their developing understanding.			
Phase 4: **EXPLAIN:** students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider *possibilities* for explanations that are original to them. They use argumentation and *dialogue* to decide on the relative merits of the explanations they formulate, *playing* with ideas.	.		
Phase 5:	Students connect their explanations with scientific knowledge, using *different ways of thinking and knowing* ('knowing that', 'knowing how', and 'knowing this') to relate their ideas to both disciplinary knowledge and to *interdisciplinary* knowledge to		.	**Studing art works in relation with the subject. Ressources**

CONNECT: students connect explanations to scientific knowledge	understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.			**are proposed on a plateform. Possibility to contact artists.**
Phase 6: **COMMUNICATE:** students communicate and justify explanation	Communication of *possibilities*, ideas and justifications through *dialogue* with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be *immersed* in a key part of the scientific process. Such communication is crucial to an *ethical* approach to working scientifically.			**Exhibition**
Phase 7: **REFLECT:** students reflect on the inquiry process and their learning	*Individual, collaborative and community-based* reflective *activity for change* both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.			

6. Additional Information

Based on this demonstrator two projects have already been proposed.

One concern last year of of primary school and first year of high school. For high school art and science teatcher were concerned. At primary school, there is no disciplinary division. One point was very important is that the high school students present the experiment to primary school class.

The other one was a big art exhibition in a real art center. Students from 4 18 y.o. have presented they work. Even if all projects were not connected to science, a special focus was made to give ideas to use scientific concepts. Teachers were in contact with a researcher working on surface sciences. A conference on Art and science was also proposed at the art center.

7. Assessment

8. Possible Extension

As there are a lot of various experiments and a lot of artistic ressources, a booklet can be prepared. This will be in collaboration with art center, artistic activities center and a laboratory of material science.

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Annex 2: Sample Data from the Methodological Tool of Qualitative and Content Analysis of 107 Demonstrators

The main Pedagogical Principles and the Educational objectives for the design and Implementation of Educational and Outreach activities for involving students in Research and Innovation process.	Qualitative Analysis of the Structure of Demonstrators									Qualitative Analysis to Pedagogical Framework (CREATIONS Features, IBSE, RRI principles, Effective Learning Environments			
		Sparking Interest and Excitement -Understand the concept of motivation -Find a challenge -Combine Challenge with RRI aspects -Combine two or more disciplines… be creative to produce new ideas		**Using the Tools and Language of Science (see Effective Learning Environments, D3.1)**		Sparking interest and excitement -Understand the concept of motivation -Find a challenge -Combine Challenge with RRI aspects -Combine two or more disciplines… be creative to produce new ideas		**Understanding Scientific Content and Knowledge** -Think the representation of a scientific concept -Use various symbolic systems to represent the scientific concepts -Think the role of Modelling as a representation process -Consider the role of Embodied learning Consider the role of argumentation	**Sparking Interest and Excitement** -Understand the concept of motivation -Find a challenge -Combine Challenge with RRI aspects -Combine two or more disciplines… be creative to produce new ideas	**Sparking Interest and Excitement** -Understand the concept of motivation -Find a challenge -Combine Challenge with RRI aspects -Combine two or more disciplines… be creative to produce new ideas **Engaging in Scientific Reasoning** -Understand and apply CREATIONS key features -Understand and apply IBSE Best Practice and Demonstrators' Generic Framework (WP2)		**Reflecting on Science** -Consider the role of self regulated learning (SRL)	
Participating Organisations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase 1 IBSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features IBSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
1.UBT-GERMANY	Bionics. Art Biology. Chemistry Art Physics. CLIL biodiversity education Biology	Educational Activities based on Creativity-enriched Inquiry Based Approaches (school based) local activity	Short term	Formal Informal (zoo)	•Simulations of the streamline shaped animals are shown in the learning scenarios, which should be visualizing the theoretical model of the moving problem in the water. Inquiry based experiments should be brought in classroom or even in the zoo. •Art based learning scenarios are located in the zoo with the hand craft work for the Fin Ray-Effect ® and some more practical experiments in the exhibition next to the zoo. •Dialogic space is given in the zoo special argumentation hour, the students can talk to experts and learn from their experience in science and also communicate about problems in the zoo and the bionic topics which are linked with that. •Experimentations are made with the students directly on the compound. They learn through 'hands on'	wrong perceptions about bionic or even NO perception. disability to think about different everyday examples they know Not using model although models and modelling take a central place in science education models serve as meditative mediators between theory and practice students have difficulties to explain macroscopic genetic phenomena by using the so called organizational micro level. a lack of motivation Alternative perceptions about evolution (biology) and bird-flight (physics) often prevent learning. Complex topics cause cognitive overload. negative image of scientific topics// languages and promoting language-learning motivation. Learning complex languages might decrease learning motivation. A negative self-efficacy might enable the development of a fluid spoken foreign language. 5	Cognitive Emotional Long life Artistic Communicative cooperative	Handicrafts creating own models drawing Experiments with models a robot is introduced to the students. It can sing and dance and is an example for bionics with humans as model.	Student: Thinking about how inventors find their ideas Teacher: Offering some ideas about technical solutions – what might have been the model in nature. A CHALLENGING QUESTIONE (1) pre-test before participating in the gene technology teaching-unit Thinking about how the police/forensic technicians could clarify a crime Offering the case of a real crime scene documented in the newspaper A QUESTIONNAIRE, SOCIETAL CHALLENGE (2) SEARCHING AND COLLECTING DATA Students are working in groups of	See: both Pupil Ability: cg (The scenario allows space for pupils of various abilities to participate) Responsible Research and Innovation (RRI) approach, because it incorporates educational activities that promote school-research center collaboration.	✓	✓	✓

Participating Organizations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase 1 IBSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features IBSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
					stations in different bionic topics. •Communication of scientific ideas is also given in the special talking round with the experts and scientists directly in the zoo. (5) •Experimentation (science laboratories): In the pre lab unit the students practice essential techniques of a scientist in a gene technology lab e.g. working with micropipettes and centrifuges./ Based on the story of a real crime the students isolate in the first experiment their own DNA out of oral mucosal cells (material level). /In the second experiment the students learn the procedure of a gel electrophoresis (molecular level) as one of the most important genetic lab work techniques. •Art-based learning scenarios: are located in the lab with the handicraft work while building a model of DNA-structure. Thereby the students are linked to the discovery of DNA-structure by Watson & Crick in 1953 and can learn from their experience. •Dialogic Space / argumentation: •Communication of scientific ideas especially in the context of modelling in science is also given space during the gene technology module at the university.	biodiversity is threatened on a global scale, its heritage for future generations is at risk Reducing biodiversity loss achieving sustainability goals, requires understanding about the main causes focusing on anthropogenic activities and interferences The pedagogical challenge herein is, that several studies report about an increase in students' alienation from nature and a lack of students' scientific knowledge on nature in general and species identification skills Lack of motivation concerning the environmental problem of biodiversity loss, only to learn about but not contribute to real-life environmental research. (8) Not understanding that Modelling is the essence of scientific thinking models and modelling take a central place in science education a tool for teacher to help them to support the cognitive ability of their students in the learning process it is an educational challenge for teachers based on their class heterogeneity of individuals with different skills (e.g. misunderstanding the text, problem to imagine and modelling a structure that is very small and not to see with a human eye or modelling untalented mentally visualizable way of linking theory with experiment weakness of different skills. Models and modeling are central to science education develop problem solving skills traditional science education (STEM – Science, Technology, Engineering, Maths) is often associated with negative perceptions, lack of motivation, and learning difficulties,			four. They read a future scenario about the problems of a forester. This raises several questions concerning biodiversity (e.g. "What is the function of deadwood?" or "What is the problem with monocultures?") COOPERATIVE METHODS Students are working in groups of pairwise. They read the text: "A journey to nerve cells" (Unterricht Biologie, 233/22, 1998). This raises several questions concerning 'how does a nerve cell looks like' and how to transfer an information.				

Participating Organizations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase I IBSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features IBSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
3. CERN	Particle Physics, Art STEM Astrophysics, Cosmology, History of Science, Engineering, Technology Astronomy	Educational Activities based on Creativity Enriched Inquiry Based Approach, Educational activities that promote school-research center collaboration (research institute, science cafés, science fair festivals science parks, museum, art space) local, national and in international level.	Short term Long term	Formal (i.e. school) but can also be informal (e.g. science café, science fair) mainly formal (i.e. school) but can also be informal (e.g. science fair festivals)	•Communities of practice •Simulations •Arts-based •Dialogic space / argumentation •Experimentation [Science laboratories and eScience applications] •Visits to research centers (virtual/physical) •Communication of scientific ideas to audience	offer school students transformative experiences that extend beyond the classroom; transform the learner's perspective; and lead to deep engagement in science Yet not all schools can afford visiting CERN mainly due to geographical and financial barriers. the abstract nature of the related phenomena which inhibit conceptual understanding and knowledge development no organized knowledge around key concepts and/or skills concerning particle physics in the form of a comprehensive curriculum. students' aspirations of pursuing a career in STEM fields, including physics science motivation and aspirations among K-6 students. continuous professional development (CPD) courses for primary teachers, development of learning resources and communities of interest follow-up support in schools and especially those that serve students from remote or relatively disadvantaged communities. promoting their creativity and their STEM skills. In this approach pupils besides learning science contents, need to become acquainted with and have an appreciation for the nature of science They need to develop skills for critically analyzing the validity of given arguments presented in the media or in public discussions as well as for coming to logical conclusions and decision making based on scientific information rather than on propaganda or bias. the absence of space and particle physics teaching at Primary School, since 2006 was the latest year that was taught something similar in the official curriculum,	Cognitive Emotional Long life Artistic Communicative Cooperative Research	dance performance inspired by the rotation of galaxies or by the collision of particles at the LHC) building particle detector models or performing a sketch. sketches, stand up comedy, music performances models, drawings comics augmented reality board. Pantomime depicting the circle of water. Creative-writing and story-telling in science: stories, poets, acronyms and enigmas about weather phenomena. Constructions and draws of the solar system Development of visual diary and/or artwork portfolio writing up of art statement. Art exhibition during which students and teachers communicate their works with the public Drawings Mind maps that can enriched with artistic drawings and picture collage Models Pupils make their own atoms from plasticine as they see them from the periodic table. Every working group dramatized the move of the	Invites students to think of and pose a "big question" in science and particularly in particle physics. Ignites students' curiosity by prompting a "big question" in science using audiovisual means (e.g. video) Invites students to think of how scientists and artists approach differently a scientific idea and its social implications. QUESTIONS AUDIOVISUAL MEANS VIDEOS+ QUESTIONS (2) Engage with teacher's questions. Watch videos and use the web to explore weather phenomena. Will use challenging questions and the web (images, videos) to attract the students' interest in weather phenomena. QUESTIONS, VIDEOS, WEBSITES	Sex: Both Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)	✓	✓	✓

Participating Organizations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase 1 IBSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features IBSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
						while science is evolving and daily presents new data to society The challenge of the project is to break the silos between science and the arts in order to highlight the importance of inter-disciplinary thinking in order for young people to understand and contribute more creatively to the complex process of knowledge creation in a global environment. tackle in their effort to inspire and engage pupils with science. This is especially the case of small rural schools located in remote islands where students have limited stimuli and resources available in their out-of-school environment to develop interest in and experiment with "big ideas" in science. In addition, there is the challenge of developing 21st century skills such as collaboration and creativity. Students need to learn from an early age how to cooperate with each other but also how to overcome deeply rooted stereotypes such as the role of women in science. Finally, they need to get familiar with different ways through which they can express themselves and communicate their thoughts and feelings with their friends and the local community. How easy or difficult is to speak and teach for particles the students to a primary school, especially in a poor neighborhood? What could be done for the success of a try like this? How can I find the time to teach all these new things in to a curriculum which is not flexible? Will be easy or hard to convince the parents about the significance of this program? Becoming a scientist for a week to participate in modern scientific research		electrons, the nucleus with the protons and the neutrons at the school yard. Students employ their imagination and creativity making in groups cosmic funnels, with simple materials. Funnels are made by cardboard, the particles, such electrons, protons, bosons, W and Z etc from rice, lentils, barley, beans, pasta, chickpeas, plasticine. Nebulae from cinnamon and galaxies from salt. Students share balloons each other and papers in which they draw galaxies that will glue on the balloons and as they blow them the galaxies will removed from each other. Every working group decorate corners of the classroom with their creations We hang on the cosmos-balloons from a rope through our classroom. Students make draws of the night sky. They use black font with crayons and bright stars. Students open the black sheet, stretch it and with a big pumpkin in the center forces the little balls to make elliptical orbits. We do a Tina's Nantsou experiment "Astronomy with milk", explain the light and the colors of the sun at sunrise and at noon. Also,					

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								etc.) they will Implement. a theatrical play, to an exhibit, a dance show, an artful video					
3. EXETER	Physics (particle and nuclear) Arts Science Teacher Development Photography Biology Mathematics Biology, Chemistry, Earth Science	Educational Activities based on Creativity-enriched Inquiry Based Approaches (school based local activity).	Short term Long term	Formal informal	•Communities of practice (web-based/physical): The action research days include a mixture of formal presentations about the project, the available resources (portal) and ethics, workshop type activities exploring the CREATIONS features. There are whole group discussions facilitated by the leader, small group discussions between teachers and mentors, presentations of existing good practice / projects, and informal icebreaker type activities. •Arts-based: the teacher pairs explore the CREATIONS features through collage making and exploratory movement activities as a stimulus to generate their own ideas for their investigation. They are exposed to a successful Science Arts project to provoke their thinking. •Dialogic space / argumentation: Questions that shape the day include: What are the CREATIONS Features? What does interdisciplinary work between the arts and sciences look like? What is Action Research? What makes a good Action Research question? What kinds of data collection tools can we use? Who can we get to use them? What ethical considerations should we be thinking about? Through questioning and dialogue the teachers will be encouraged and allowed to express their ideas on how to shape their Action Research project.	Often in science education there has been an emphasis on teaching approaches that are rooted in scientific method (e.g. argumentation, practical work and investigation). These often lead to communication of scientific ideas using genre-based reporting that pupils can find disengaging develop students' understanding and to communicate this understanding to their peers conversive trauma" (Hargreaves, 1983) which suggests that the affective reaction to a work of art can be the stimulus to find out about the processes involved in its creation, rather than understanding of those processes being the basis on which the affective response is based. that one purpose of science practical work in schools is to give pupils a 'feel for the phenomena' Students tend to view subjects in isolation, not even transferring skills from math's to science, linking art and science provides a challenge. generates enthusiasm and motivation to engage with scientific content, whilst demonstrating to them that they can use knowledge and skills from one subject to inform another. Pupils are regularly challenged to relate the discovery process in Science to more abstract scientific contexts they are required to learn (Bennet, Lubbe & Hogarth, 2007). In particular, elements that are perceived as 'dry' and requiring practice need to be brought to life and grounded to make them more accessible to a wide range of pupils. Similarly, reference to the history of science is often limited in the curriculum to relatively few key figures, who are largely white and	Cognitive Emotional Long life Artistic Communicative Cooperative Metacognitive Interpersonal intelligence Body kinesthetic	through a film with narrative a dance performance a poem photographs or videos of objects / issues photography, audio recording, reflective diaries, creative writing Graffiti representing the shoal of fish conceptual drawings of what "being the." looked like in different subject areas. Playing and experimenting with paints and color with a "what happens if?" approach rather than led didactic teaching with predetermined outcomes. The main making in art was through experimentation with various materials and students created their own responses relevant to their own line of inquiry derives, sketches, guided walks, blind folded partner navigation, photographic quadrats, free-	Children and young people will choose an art form to best represent their science topic, perhaps using IBSE. This is however unlikely to map directly onto the IBSE stages to the left, but to encompass science knowledge/processes in a more holistic way e.g. through a film with narrative: through a dance performance embodying a science concept, through a poem engaging with key physics principles. They may ask teachers for assistance if they are available but are also likely to draw on artist/scientist expert mentoring via the competition website. REPRESENTATION TALK BY SCIENTISTS, DISSCUSSION, QUESTIONS, VIDEOS IMAGES, VIDEOS,	Sex: both Pupil Ability: egg (The scenario allows space for pupils of various abilities to participate) i.e. university partnership emails, advertise on the university website, social media platforms and teacher specific websites like the TES. To include mindfulness activities with and environmental focused project through visits to local nature areas (beach, woods, moorland). •Encourage awareness of sustainability issues facing the planet through work involving plastics (using plastic generated within the center to create an art installation and possible beach clean).	✓	similar techniques could also be used to engage with living or imagined scientific figures; for example, students could create dramatic representations of the types of scientists that they might envision themselves becoming, or scientific innovations that they would like to lead. This type of activity would also encourage students to consider the limitations or barriers that might be placed in their way – whether social, moral, economic or intellectual – and how they	✓

Participating Organizations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase 1 RSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features RSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
						importantly their self-esteem and confidence to re-engage in any aspect of learning. science can be to see it as transmission-led learning focused on learning scientific facts, when in fact school science has the capacity to be about the dialogic relationship between important questions and how we use knowledge to answer these creatively. There can also be a tendency to approach science in a risk-averse way which is detached from students' real-life experiences because of the pressures of attainment targets. relate to students' identity development as investigator							
4.NKUA-GREECE	Biology, Engineering, Technology Arts Mathematics , Physics, Chemistry, STEM Mathematics , STEM Geometry, science - Astronomy General	Educational activities based on Creativity-inquiry based approach Educational activities that promote school research center collaboration a local level	Short term Long term	Formal Informal (science museum)	•Communities of practice (web-based/physical) •Dialogic space / argumentation •Visits to research centers (virtual/physical) •Communication of scientific ideas to audience •Communities of practice •Arts-based •Experimentation (Science laboratories and eScience applications)	Although argumentation consists a core feature that accommodates the epistemology of science, science education has failed to incorporate it in its didactics. By excluding the element of argumentation has a "dialectical approach" -from the learning process of the science classes. we fail to instill in students the challenging aspect of scientific inquiry Students deprived of this scientific procedure, either verbally by the lack of argumentation language or practically by the absence of inquiry practices, perceive science as a ready to consume product and an authoritative and sterile field that allows for no challenging exploration. students fail to face and clear up the misconceptions they have on scientific issues and concepts since ready made and indisputable explanations offered by their teachers leave no room for scientific reasoning and construction of scientific knowledge based on the ground premises of mental exploration, testing hypotheses, data collection and consequent discursive exploration. Traditionally the body has not been used in education.	Cognitive Emotional Artistic Cooperative Professional	Students make a collage of snapshots (taken from videos, journals, etc.) explaining the state of the art with reference to the thematic topic they're exploring. storytelling (e.g. How scientific progress in the specific field has affected (improved or deteriorated a person's life). models/ drawings to strengthen their explanations. videos (possible future scientific applications: Provide creative theatrical scenarios/scripts final 2-day science theatre event Create drawings to illustrate the history of particle physics and identify milestones	QUESTIONS, WEB SITES	Sex: Mixed Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate) The SP approach is grounded on the respect for students' needs and interests as a cornerstone for its successful realization. The selection of the topic and the exploration of relevant issues depend on students. During the inquiry phase all students will participate and contribute with relevant to their interest data. The Human Brain, Living and eating healthy- but how, stem cells- the potential allrounders, Augmented human: optimizing the human, imitating nature Depending on the science topic, as a stimulus, pupils present any issues, ethical concerns or consequences surrounding this	✓	✓	✓

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						Although our expanding society strongly depends on engineering to shape and build new transport 'paths' to connect people and facilitate transport is not formally included in our primary education curriculum –only addressed through individual projects since young children from a really early age, even before attending infant school they demonstrate a tendency and show great fascination in taking things apart, disassembling and assembling them, driven by an inner curiosity to figure out how things work. These challenges are firstly relevant to the educational practices and the purposes of school education. One of the main problems of the most school systems, included the Greek education system, is the students' lack of motivation. students cannot connect science education to their everyday lives. Moreover, they find teaching methods old or inappropriate for their acquisition of knowledge, as these are not creative and challenging. The problem of the distance between school knowledge and students' everyday needs is obvious although most school curriculums have managed to simplify scientific knowledge to school knowledge, they have failed to deal with modern scientific notions according to the global, new findings on science. Consequently, students cannot connect their knowledge to new findings on science and technology and as a result they are not able to develop a science literacy							
5. EA- GREECE	Intraparticle physics, history of the Universe Arts Physics, Mathematics Arts Geology Music	Educational activities based on Creativity-Inquiry based approach Educational activities that promote school-research	Short term Long term	Formal and informal (research center)	•Communities of practice (Students groups) •Dialogic space / argumentation (Science café) •Arts - based •Experimentation (Science laboratories and science applications) •Simulations (digital/physical, computer labs)	Questions like, "what are the basic building blocks of matter?", "What are the fundamental forces of nature?", "Could there be a greater underlying symmetry to our universe?", still remain to be answered. Particles such as neutrinos or Higgs bosons are expected by revealing their secrets to play a major role in putting the pieces of the		Creation of science stories by the students, storytelling, script writing. Acting, script writing, directing etc. Finalization and Rehearsals of students' short plays Actor group:	QUESTIONS, WEB SITES, GAME	Sex: Both Pupil Ability: The scenario allows space for pupils of various abilities to participate. Sex: both Pupil Ability: mixed (the scenario allows space for pupils of various abilities to participate). Pupils	✓		

Participating Organizations/ Partners	Subject Domain	Type of Activity	Duration	Setting	Effective Learning Environment	Challenge	Objectives	Potential Art Activity	Motivation (Phase 1 IBSE)	RRI aspects (Combine Challenge with RRI aspects)	CREATIONS key features IBSE Best	Reflecting on Science	Identifying with the Scientific Enterprise
		center collaboration (Summer school for students including lectures, workshops, visits to Research Infrastructure (physical visits/ virtual visits), use of online analysis tool, science café, public presentations. Small scale Activity at local or national level.			•Visits to research centers (virtual/physical) •Communication of scientific ideas to audience (theater stage)	puzzle in the right places and tell us the history of the universe. neutrino's particular features and properties Concepts as these described above, usually are not studied thoroughly or even included in the curriculum challenge of explaining a scientific concept through sound. The approach that the demonstrator adapts towards this task is threefold •Symbolic (the connection between sounds/music in comparison with the scientific concept is purely artistic) •Mathematic (the connection between science and the Arts is directly reflected in pure mathematics) •Adaptive (which is a combination of the above) Becoming a scientist for one day to participate in modern scientific research Employ creativity and teamwork to analyze and communicate scientific results with the general public in an artful fashion. Understanding advanced scientific topics beyond the reach of school curricula. Despite the large visibility of such major scientific discoveries through the media and the press, the school curriculum has been left behind, excluding modern science and teaching physics that date before the 20th Century. Students are not able to comprehend the results of cutting edge research and educators are in their vast majority not in a position to answer students' questions which are sparked by their natural curiosity. This results in students' decrease of interest in science and in the prospects of following a scientific career, and a drop-in educators' confidence and self-esteem.		Music group: choreography Set/costumes group Video group script group and collect or create video teleconference "virtual stage" Students may use drawings, photo or video collages, handmade exhibits to aid them communicate their experience. Experimentation with sounds of earthquake. Students perform their musical syntheses by combining the waveforms they have analyzed with the sounds of different musical instruments in an online environment. They match waveform amplitude to notes and using a sonification protocol they play their own melodies. Story The artistic analogy of a student to a particle through the Ignite mode of the LHC tunnel., Video presentation. Creation of artwork Every art activity		with music background in secondary levels are encouraged to produce material or participate in activities that motivate their fellow students. Sex: both Pupil Ability: Basic computer usage required			