

D2.3 Effective learning environments for inquiry learning and teaching

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Short Description:

This deliverable aims to present the characteristics of learning environments that support teaching science by creativity-enriched inquiry. The specific characteristics will be presented in a generic framework that will be in alignment with the CREATIONS pedagogical framework.

List of Recipients:

- Project Partners
- EC

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1 Executive Summary

This deliverable aims to present the characteristics of learning environments that support teaching science by creativity-enriched inquiry. The specific characteristics will be presented in a generic framework (see section 2.2) that will be in alignment with the CREATIONS pedagogical framework.

The characteristics of the CREATIONS learning environments have been identified and developed considering: (1) partners' inputs on a pro-forma template, requiring their contribution on the identification of specific characteristics regarding the learning environments (Annex A), (2) relative EU projects that aim to promote and support science teaching by creativity-enriched inquiry (PATHWAY, Discover the COSMOS, CREAT-IT) and (3) literature review on key elements and characteristics for the design of effective learning environments that enhance creativity and Inquiry-based approaches.

1.1 Challenges in Designing Effective Learning Environments that Support Creativity in Inquiry

There is a rich tradition of using physical materials for hands-on science inquiry, but that tradition has had little influence on the ways computers are used in educational settings. The CREATIONS approach to bridge this divide, introducing new technologies and creative activities that fluidly link the use of physical materials with digital technology in creative inquiry and inventive exploration. The partnership explores the integration of physical and computational media for the design of interactive learning environments to support learning about complex scientific phenomena. This set the basis for the design of interactive learning environments to integrate systems supporting alternative ways of interaction with simulation and modeling tools - with an emphasis upon support for shared interaction to mediate social aspects of learning, knowledge construction, reflection and design. As long as the demanding school curriculum extends through fields of science that constantly evolve, both the treatment of raising interest between students in real classroom environment as well as the need for deep learning, will be facing the challenge for enhancing informal teaching approaches. Performance art as one of the

main informal creative-science tools is able to serve as a link between creative learning and the suggested pedagogies described below:

Creativity aspects

Furthermore a recent ethnographic study by Craft et al (2013) discovered that there were three key characteristic features of creative pedagogies shared across the schools.

1. Co-construction. In each of the two schools, shared reflections were valued and inclusive teaching approaches that involved the pupil and teacher were actively embraced. Rojas-Drummond et al (2006) characterise co-construction as the 'joint efforts of coordination, negotiation and collaboration in various group work activities' (92). The researchers noted that the 'important feature of co-construction in each school was emphasis on real life contexts and relevance' (Craft et al, 2013: 11). The study reports how researchers recorded teachers co-constructing the curriculum, while at one school the children had been designing their own pathways for many years.

2. Children's control / agency / ownership. Each school provided 'a trusting, agentic environment' that encouraged 'children's decision making, offering them ownership and control over their learning' (Craft et al, 2013: 12). At one school the study reports how the children's **control, agency and ownership were fostered through creative and reflective practice that supported and enabled their ideas.** The teachers felt empowered as they had the freedom to plan what the children were interested in and the children became more engaged as they had agency over the curriculum. The **children were also involved in developing spaces that documented their work, thus they were motivated, and more confident as their self-expression was allowed.**

3. High expectations in skills of creative engagement. The final characteristic of the creative pedagogies identified by Craft et al (2013) was that teachers in each school set 'high expectations in skills of creative engagement'. The teachers observed during the ethnographic study held 'high expectations in relation to the development of children's skills in learning' (Craft et al, 2013: 14). Staff were encouraged to have high expectations as they were supported through professional development opportunities and on going shared reflection and learning.

They recommend that schools need to improve their **learning environment** so that children can nurture and develop a deeper understanding of education in contrasts to their perception that children are being taught by rote. The content of the curriculum needs to be **engaging** so that students are challenged to achieve academic excellence, and finally that the **community of learning needs to be broadened** so that the boundaries of learning are extended beyond what is considered the traditional classroom.

Similar to De Moss and Morros, Eisner (2004) also argues for a strong shift in the US education system. He describes six artistically founded qualitative forms of thinking.

- The ability to compose purposeful qualitative relationships
- The formulation of aims
- That form and content are inextricable
- That not everything knowable can be articulated in propositional form
- There is a relationship between thinking and the material
- Motives for engagement

By proposing the question what minds we want our children to have, Eisner considers that a child is not born with his or her mind that it is shaped by experience and culture. He cites that the arts promote a different kind of thinking and that education can learn from this, but to achieve this would require schools, staff and students to change their perception of learning. Eisner suggests that the arts play a motivational role and can encourage students and teachers to be 'flexibly purposive' to encourage children to learn via their curiosity and to prepare teachers to allow for the unexpected.

One way of understanding how learners and adults connect creatively is to consider this through McWilliam's improvisational concept (2008) of the teacher as 'meddler in the middle'.

Meddling in the middle: Teaching creatively and teaching for creativity

In teaching creatively and teaching for creativity (particularly the latter) there are assumptions about the active involvement of learners and their own meaning-making, which drive pedagogy and shift the relationship between learner and teacher into a particular kind of dynamic.

Further, building on Woods' work, Jeffrey's (2006) Creative Learning and Student Perspectives (CLASP) project, was a two-year European Commission funded report that involved nine countries including: Austria, Denmark, England, Ireland, Poland, Portugal, Scotland, Spain and Sweden over 22 months (2003-2005). The report explored creative teaching and learning in primary and secondary contexts across Europe and identified the following pedagogical strategies as vital to what might be understood as 'guide on the side' approaches to fostering creativity in children's learning in a range of domains of knowledge:

- **The establishment of real and critical events and strategic external co-operations.** Such critical events frequently developed over time and revealed all four of Woods' process of relevance, ownership, control and innovation in action. Critical events were often encapsulated within a special period of time – sometimes integrated with parts or the entire curriculum and sometimes operated as separate though there was usually an indirect or direct engagement with particular domains of knowledge. Critical

events usually also involved a great deal of collaboration with others beyond the school (artists, specialist funders, advisors, visits, project specialists, workshop providers). Despite the pressures on assessment and testing across Europe within much narrower elements of the curriculum (Ball, 2000), each of the sites researched drew strength from its critical events and strategic partnerships to resist these. Two particular aspects of critical events were highlighted by the research team.

- **Creative Use of Space.** This pedagogical strategy was often linked with critical events, which frequently involved changing the nature of learning spaces, and indeed often involved moving the whole teaching group into unusual actual and virtual learning spaces. The re-design and re-use of space though was not always, the project reported, successful. Not all students found it easy to engage in new learning contexts and the research team interpreted this in relation to the 'cultural capital' which children brought to the learning context (Bourdieu and Passeron, 1977).
- **Creative Use of Time.** Time was often stretched, lessons lasted longer and continued as long as interest was sustained giving time for depth of engagement, and, being linked to the critical events, signalled the importance of the critical event in fostering interest and commitment.
- **Modelling Creativity.** Alongside critical events, Jeffrey (2006) reported that teachers across Europe modelled creativity, being aware of their capacity to influence their pupils. They therefore took a real interest in children's ideas, celebrating these, put significant time into discussion and critique, worked alongside and in collaboration with partners such as artists and workshop leaders and acted spontaneously, engaging in learning and demonstrating pleasure at innovations generated (something previously noted by Jeffrey and Woods, 1997 in an earlier ethnographic study and indeed later, Woods and Jeffrey, 2006). Spontaneous activity also included making changes in plans to classroom activity.

These classroom strategies documented by Jeffrey (2006) for fostering creativity in late primary and early secondary education are also found in creative partnership between artists and teachers that focus on the fostering of creativity in specific curriculum areas.

ICT and Research Infrastructure Aspects

The school as we see it today has to go through radical changes, the Creative Classroom of Tomorrow is equipped with computers and broadband internet access for all students. Students will design their own path and acquire knowledge at their own pace. Teachers of tomorrow must assume the role of tutors and guide students while they are building their own trajectory. Each



individual should have their own path. Modern means for communication and information exchange are becoming available at fast pace and equipping schools for this new reality is expensive and demands a lot of renewing and training. The evolution of technologies is a never ending story. But the integration of these tools in schools practice has never been more demanding: on the schools infra-structure and on the teacher practice.

Despite the fact that several of this important new movements in technology are around for over 20 or even 30 years, they are still out of the classroom. Take for instance the internet or personal computers. We know that the majority of the students possess computers at home and internet access, at least in Europe so current information is at a distance of a click. We know that students are bombarded with TV shows with amazing graphic quality presenting science topics and still the classroom of today is filled with text books, with the heavy cost that represents to our environment. Books are precious and those who appreciate a good reading know the value of this good companion, but these are the precious friends that we need and want to keep forever and not the outdated books that try to introduce us to the magic of the scientific world. Some of them actually do a good job, but nothing replaces the thrill of a science discovery, especially if you are a student and you suddenly understand the power of the scientific method. Students are being born in a highly technological world. To them the classrooms are nowadays a sort of travelling to the past and they want to embark in the spaceship of the future. So here is the challenge, we are living in a very demanding time and bright solutions to make this shift are important.

So we propose to build the **Creative Science Classroom**.

As in the words of Ken Robinson "we are getting our children through education by anaesthetizing them, we should be waking them up, to what they have inside of themselves". We should not educate them in bundles as if they have no individuality. We must now detour from a perfect road that brought us from the past to the present and enter the road to the future. The cornerstones of our proposal are:

Teachers as tutors: Teachers are the ones responsible for the training of our children. They have the power to change the way students perceive certain topics. A good educator must have a good background about the topic to be addressed, research skills to find the best adequate content to address the different topics and above all the capacity to inspire and motivate the student. This mission is not easy, in particular in an epoch where lessons about almost everything are freely available on the web. So perhaps the time has come to redesign the role of the teacher. Why not learn that particular mathematics content using Khan Academy or learn astronomy with Neil de Grase Tyson. Teachers can be the ones selecting these resources and helping students build their own learning journey according to their individual needs and skills. This type of approach might prove to be more adequate to the student and rewarding for the

investment teachers have to make in each new tool and discovery introduced in their daily lessons.

Individual journeys: The modern tools that we suggest to be integrated in every classroom associated with the open resources repositories and free access to databases and e-Infrastructures brings a new degree of freedom to the classrooms. Students can prepare their own learning journey tailored to their specific needs and interests while monitored and tutored by the teacher. Teachers must adopt the role of tutors and students develop their own trajectory in individual solutions. Students training need to encompass mandatory new skills such as creativity, communication, technical, problem solving, decision making, learning to learn, etc.

Use of modern tools in classroom: We must integrate in classrooms all modern components that are nowadays part of our routine: computers, internet access, tablets, smartphones, and serious games. *Students are lacking motivation to study science and acquiring basic literacy. To target this issue we need to introduce in classroom the real world experience in both ends, the reason why we should study it (connected to the student daily experience) and the integration of research based science education in school curriculum.* Collaborative work and projects must also integrate the student training but the approach to these proposals must be a modern one recurring to the available tools: collaborative spaces, social network, internet communication tools, etc.

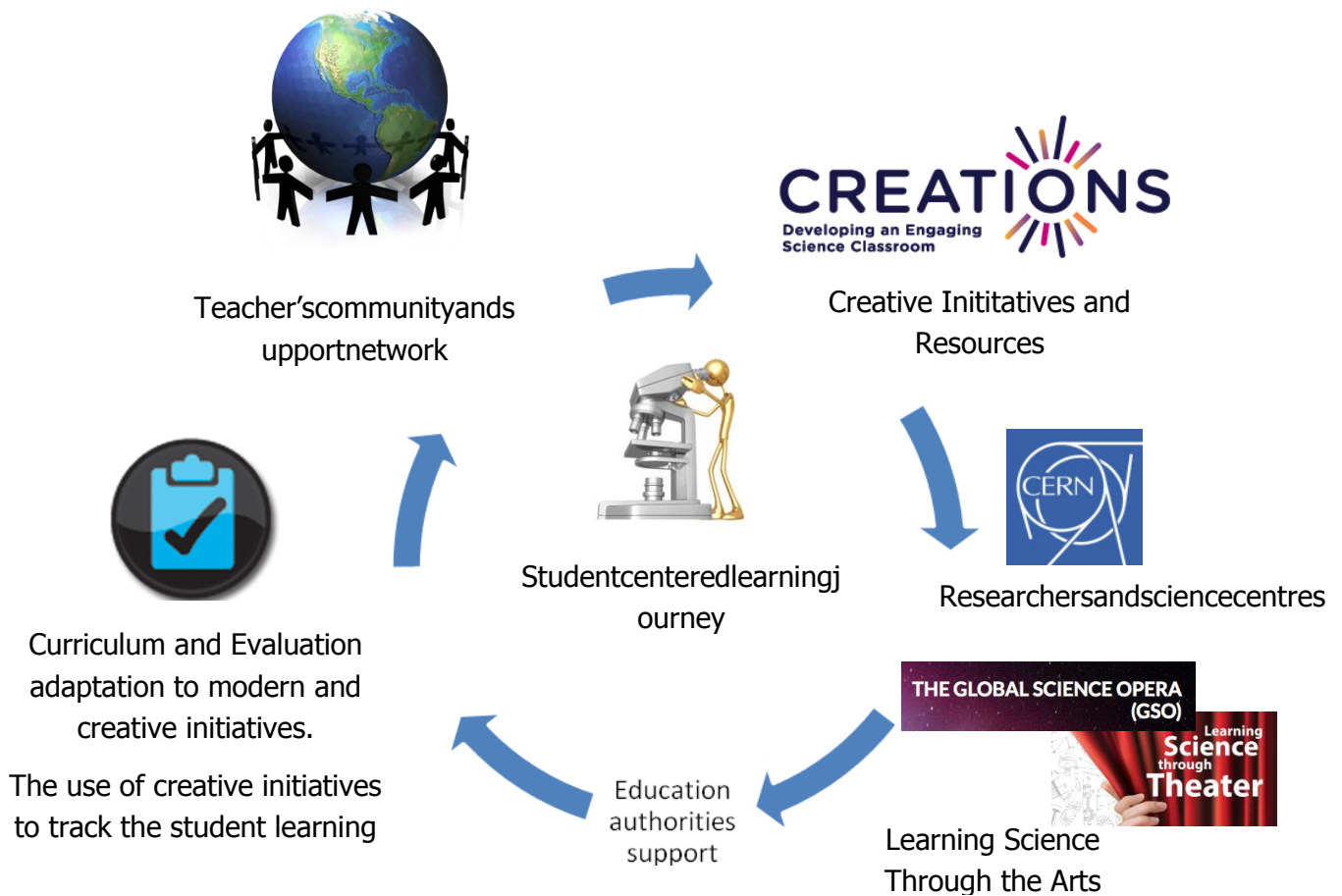
Open Repositories of Resources: *The use of repositories of information is becoming more and more a daily experience. The task to retrieve information on the web is gigantic and teachers have no or little time for this task. Repositories of contents, properly categorized, rated and classified is a good asset to any educator. This community driven repositories of resources must be fostered and embraced by the school community.*

Open access to eScience tools and infrastructure: *Part of such repositories must rely on existing tools and infrastructures for science teaching and learning. Discover the Cosmos is one example of such facility. In these spaces educators will find modern tools and resources, usually freely available, which are adequate to the specific topic being addressed by the students. Moreover many of these tools are produced by research teams and bring their scientific data, sometimes immediately after they are taken, to schools. Several examples of such repositories of data are available and allow the student to replicate the path of a science discovery or even make new ones.*

Curriculum and evaluation adequacy: *The cross-disciplinarily must be integrated in school curricula. Programmes need to be less ambitious in terms of content delivery and more rigorous in terms of skills and capacity building. Successful models like the IBSE require more time to be implemented and this, in association with the individual learning journey, demand a different type of assessment and evaluation.*

***Communities and network:** None of the above can be achieved without a strong support from the school community. In particular all the teaching team needs to take part as actors of change. The shift towards the Classroom of the future needs to be embraced by the whole school and adopted by all educators. Support of the local community is fundamental and the link with local research facilities, science centres, etc. highly desirable.*

How do we **connect all the parts** of this vision and have in place all the partners for this journey:



1.2 Implemented principles in the identification and structure of Learning Environments

The design and development of CREATIONS Learning Environments is informed and grounded on the CREATIONS pedagogical framework and inquiry and creative learning approaches to accommodate innovative and rich in creativity practices regarding science classrooms across Europe.

Grounded on the **CREATIONS“Pedagogic Principles for the design of the Educational and Outreach Activities”** there have been developed flexible learning environments accommodating and supporting a set of science-specific capabilities addressing both formal and informal educational settings. In addressing the aims of this deliverable it is important to consider that the learning environments and their characteristics should reflect and have embedded the principles of creative pedagogies and inquiry-based learning that have been identified in the CREATIONS pedagogical framework.

The main Pedagogic Principles and the Educational Objectives for the design and implementation of CRAETIONS Learning Environments for involving students, teachers and all kinds of stakeholders in Research and Innovation process are:

CREATIONS Key Principles	<i>Educational Objectives</i>
Sparkling Interest and Excitement	<i>Experiencing excitement, interest, and motivation to learn about phenomena in the natural and physical world</i>
Understanding Scientific Content and Knowledge	<i>Generating, understanding, remembering, and using concepts, explanations, arguments, models, and facts related to science</i>
Engaging in Scientific Reasoning	<i>Manipulating, testing, exploring, predicting, questioning, observing, analysing, and making sense of the natural and physical world.</i>
Reflecting on Science	<i>Reflecting on science as a way of knowing, including the processes, concepts, and institutions of science. It also involves reflection on the learner’s own process of understanding natural phenomena and the scientific explanations for them.</i>

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<p>Using the Tools and Language of Science</p>	<p><i>Participation in scientific activities and learning practices with others, using scientific language and tools.</i></p>
<p>Identifying with the Scientific Enterprise</p>	<p><i>Coming to think of oneself as a science learner and developing an identity as someone who knows about, uses, and sometimes contributes to science.</i></p>

At the same time the CREATIONS Learning Environments are informed by the main principles of **Responsible Research and Innovation (RRI)** process that includes empowerment and agency, dialogue, individual, collaborative and communal activities for change and ethics and trusteeship, Discipline knowledge and professional wisdom.

The RRI aspects that should be considered are:

- **Governance** -Change attitudes of researchers/Communicate with audience
- **Public engagement** -Engagement through involvement of students and teachers
- **Gender equality** -Girl and boys are equal through these activities
- **Science education** -This is our core aim. Participants learning by doing
- **Open access/open science** -Open access to thousands or recourses
- **Ethics** -Teamwork, role playing, role exchange develop ethics
- **Sustainability** -Develop by the teams of students and teachers, self sustain system
- **Social justice/inclusion** -All equal in this procedure, all participate and contribute

2 CREATIONS Learning Environments Template

2.1 *Applied methodology for the design and structuring of CREATIONS Learning Environments*

The Creations Learning Environments will act as a hub to enable the development of **Educational and Outreach Activities** in the form of CREATIONS Demonstrators that will be produced as a communal contribution and rich in expertise regarding the consortium. Towards this aim partners (CERN, EA, IASA, HSH, NKUA, EXETER, UBT) contributed to this effort by providing essential characteristics that the learning environments should accommodate to ensure the inclusion of all scientific capabilities and requirements. Considering the configured data we managed to address certain key issues in the development of learning environments and their underlying characteristics:

- identification of the leaning environments' ability to support the requirements established by the CREATIONS pedagogical framework and principles
- presentation of the learning environments creative and innovative affordances
- setting the context of their implementation and usage, considering their contribution to the learning process and their exploitation by students, teachers (both university and school teachers), policy makers and stakeholders that have adopted a creative and inquiry-based approach.

In addition to the above key elements, the structure and underlying characteristics of the CREATIONS learning environments have been identified by also considering: (1) partners' inputs regarding the specific focus area of the learning environments (see section 2.2) and their characteristics but also inputs on the context and structuring of the CREATIONS Initiatives (Annex B) in order to ensure and validate inter-consistency and inclusion of all key elements that learning environments should address, (2) relative EU projects (PATHWAY, Discover the COSMOS, CREAT-IT) and (3) literature review on key elements and characteristics for the design of effective learning environments that enhance creativity and Inquiry-based approaches.

2.2 *Partners' inputs regarding the learning environments and their underlying characteristics*

The following templates illustrate the partners' inputs addressing the structuring and context of the CREATIONS Learning Environments as a means to identify main objectives and synthetic components that would meet all requirements and needs in the adoption of creativity-enriched inquiry approaches.

1. Global Science Opera in Real Time (GSOrt) - EA's contribution

<p>Learning environments(physical and computational media involved)</p>	<p>A customized videoconference environment serves as a live online stage shared by schools collaborating with each other in order to create a live audiovisual web-event.</p>
<p>Characteristics of learning environments</p>	<p>The characteristics cover nearly all aspects of the project's pedagogical principles such as:</p> <ul style="list-style-type: none"> ➤ Interrelationship of different ways of thinking and knowing ➤ Pluralities, possibilities, participation, playfulness (Craft, 2011) ➤ Individual, collaborative and communal activities for change ➤ Risk, immersion and play ➤ Dialogue ➤ Public engagement ➤ Sustainability ➤ Social justice/inclusion ➤ Interactive engagement
<p>Bibliography on effective learning environments</p>	<ul style="list-style-type: none"> ➤ Craft, A., Ben Horin, O., Sotiriou, M., Stergiopoulos, P., Sotiriou, S., Hennessy, S., Chappell, K., Slade, Ch., Greenwood, M., Black, A., Dobrivoje, E., Timotijević, Đ., Drecun, A., Brajović, A., Belmontecinzia, C., Conforto, G. (2016), <i>CREAT-IT: Implementing Creative Strategies into Science Teaching, New Developments in Science and Technology Education, Springer, Innovations in Science Education and Technology Volume 23, DOI 10.1007/978-3-319-22933-1, 163-179.</i> ➤ CREAT-IT Pedagogical Framework, http://www.opendiscoveryspace.eu/node/822174 ➤ Sonia PEINADO, José Miguel MOTA, Anke BERNS, Manuel PALOMO-DUARTE, Juan Manuel DODERO, Stefano MARTELOS, Rosa DORAN, Aušra LINGYTE, Christine J. ARNOLD, Kerstin BISSINGER, Orlin KOUZOV, Eleni CHELIOTI, Stephanos CHEROUVIS, Petros STERGIOPOULOS (2015). Experiences of technology-rich innovation in European schools within the Open Discovery Space project. <i>Education in The Knowledge Society, journal.</i>

2. The Imagineerium - EXETER'S contribution



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<p>Learning environments(physical and computational media involved)</p>	<p>Classroom: altered and evolving in bespoke ways to provoke responses to the tasks and encourage attention to learning capacities required e.g. collaboration (support, challenge, role, responsibility); perseverance (thinking in different ways, being resourceful, being open to new ideas and trying them out)</p> <p>Professional maker space / creation centre, with materials and tools for experimenting / making</p> <p>CAD (Design123) software</p>
<p>Characteristics of learning environments</p>	<p>Messy, full of colour, found / recycled materials / soft and hard textures, workbenches, tools ... biscuit and drinks hub.</p> <p>Interactions characterised by equality and respect for children as apprentices and creators</p> <p>Experiential and practical pedagogies: embodied learning, testing how the mechanisms to be used feel and work in the body; practical / hands-on problem solving with materials and in mastering techniques</p>
<p>Bibliography on effective learning environments</p>	<p>Conference presentations related to the Imagineerium:</p> <ul style="list-style-type: none"> - 'Engineering the imagination? STEM learning in an arts context' by Jo Trowsdale, ECER 2014 - 'Researching Creativity Creatively' by Jo Trowsdale with Sue Challis, BERA 2015 - 'Being and Learning "like me" – developing learners through an arts and engineering partnership by Jo Trowsdale, BERA 2016 <p>Project Report: The Imagineerium Pilot Project 1 – with schools July 2014 - Jo Trowsdale with Sue Challis</p> <p>Under review:</p> <ul style="list-style-type: none"> - 'Imagineering: imagining and creating across the arts and engineering through collaborative art-making' by Jo Trowsdale in 'Creativity and Social Interactions', Special Edition of <i>Creativity: Theories, Research, Applications</i> - 'Considering the affective potential of art-making processes to foster personal relevance in science education' in 'Beyond STEM education: toward the integration of the Arts' Special edition of <i>International Journal of Science Education</i>

3. Engaging students in High Energy Physics - IASA's contribution

Learning environments(physical and computational media involved)	<ul style="list-style-type: none"> ➤ Classroom ➤ University ➤ PC labs
Characteristics of learning environments	<ul style="list-style-type: none"> ➤ Science education ➤ Open access/open science ➤ Interactive engagement
Bibliography on effective learning environments	<ul style="list-style-type: none"> ➤ S Vourakis and C Kourkouvelis, HY.P.A.T.I.A. – An Online Tool for ATLAS Event Visualization, Volos summer school 2013 proceedings ➤ Stylianos Vourakis, Bringing high energy physics to the classroom with HY.P.A.T.I.A., ICNFP Kolympari 2013, EPJ Web of Conferences 71, (2014) 00137 ➤ C Kourkouvelis and S Vourakis , HYPATIA-An online tool for ATLAS event visualization, IOP science Physics Education, Volume 49 Number 1, 2014 Phys. Educ. 49 21 doi:10.1088/0031-9120/49/1/21 http://iopscience.iop.org/0031-9120/49/1/21/ ➤ Christine Kourkouvelis and Stylianos Vourakis on behalf of the ATLAS collaboration, How the HYPATIA analysis tool is used as a hands-on experience to introduce HEP to high schools Presented at the ICHEP 2014,Valencia, Spain, Valencia 2014, Nuclear Physics B Proceedings Supplement 00 (2014) 1–7 : 10.1016/j.nuclphysbps.2015.09.198 ➤ C.Kourkouvelis and S.Vourakis, Introducing HEP to schools through educational scenaria, EPJ Web of Conferences 95,03021 (2015) DOI:10.1051/epfconf/20159503021 ➤ Stylianos Vourakis, Christine Kourkouvelis and SofoklisSotiriou, The interactive “HYPATIA” tool as a good practice science education resource of the “Go-Lab” FP7 European project , International Conference New Perspectives in Science Education, Florence 2015, to be published in proceedings ➤ Dimitris Fassouliotis, Christine Kourkouvelis, Stylianos Vourakis , Introducing HEP to university students through web based simple hands-on analysis – ICNFP Kolybari 2015 ➤ Involving students in HEP research with the help of the “Inspiring Science Education” and “Go-lab” European outreach projects – EPS 2015 Vienna

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- Stylianos Vourakis, Dimitris Fassouliotis and Christine Kourkoumelis An advanced Go-Lab scenario for the GUI-based analysis of large samples of particle physics data REV 2016, Madrid
- Dimitris Fassouliotis, Christine Kourkoumelis, and Stylianos Vourakis The Inspiring Science Education project and the resources for HEP analysis by university students ICNFP 2015

4. Global Science Opera (GSO) - HSH's contribution

<p>Learning environments(physical and computational media involved)</p>	<p>This depends on how each school/institute will choose to participate. A typical school participation which chooses to perform part of the opera will have these environments:</p> <ol style="list-style-type: none"> 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. Access to scientific information (teacher/internet/book/research center) 6. Good internet connection
<p>Characteristics of learning environments</p>	<p>The learning environment in GSO is global. This necessarily includes networking with countries beyond the European context. This is done by a monthly meeting online during which the various partners meet to discuss the opera's progression (note: for the 2016 production, these will commence in March).</p> <p>The process is collaborative, creative and flexible. It includes elements which cannot be foreseen in advance.</p> <p>For the classes which are performing, 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. Time zones must be considered, and sleep-overs may be needed for e.g. Australian pupils.</p>
<p>Bibliography on effective</p>	<p>Garoian, C. R. & Mathews, J. D. (1996). A common impulse in art</p>

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learning environments	<p>and science. Leonardo 29(3), 193-196</p> <p>Craft, A. (2011). Creativity and Education Futures. Changing Childhood and Youth in a Digital Age.</p> <p>Ben-Horin, O. (2014). The WASO Guidelines. EC: CREAT-IT project. Available at: http://www.opendiscoveryspace.eu/edu-object/write-science-opera-waso-guidelines-820499</p> <p>Ben-Horin, O. and Stergiopoulos, P. (2015). "SkyLight – a Global Science Opera Implementation Scenario". Available at: http://www.opendiscoveryspace.eu/edu-object/skylight-global-science-opera-waso-implementation-scenario-833946</p> <p>TV Report, Brazil: http://g1.globo.com/rj/norte-fluminense/rjintertv-2edicao/videos/t/edicoes/v/alunos-de-campos-rj-representam-o-brasil-em-evento-que-reune-opera-e-ciencia-na-web/4513893/</p> <p>Online article: http://galileoteachers.org/skylight-a-global-science-opera/</p>
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5. Write a Science Opera (WASO) - HSH's contribution

Learning environments(physical and computational media involved)	<ol style="list-style-type: none"> 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)
Characteristics of learning environments	<p>The learning environment in WASO 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.</p>

Bibliography on effective learning environments	<p>Garoian, C. R. & Mathews, J. D. (1996). A common impulse in art and science. <i>Leonardo</i> 29(3), 193-196</p> <p>Craft, A. (2011). Creativity and Education Futures. <i>Changing Childhood and Youth in a Digital Age</i>.</p> <p>Ben-Horin, O. (2014). The WASO Guidelines. EC: CREAT-IT project. Available at: http://www.opendiscoveryspace.eu/edu-object/write-science-opera-waso-guidelines-820499</p>
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6. Bionics – out-of-school learning in the zoo - UBT's contribution

Learning environments(physical and computational and media involved)	<p>In cooperation with the "BIONICUM" at the zoo in Nuremberg a curriculum compliant learning circle about Bionics was established (6th grade).</p> <p>The intervention provides selected bases around the theme of bionics and their diversity.</p> <p>Students gain an overview about different bionic areas and learn the bionics concept and its importance to know.</p>
Characteristics of learning environments	<p><u>Learning circle</u></p> <ul style="list-style-type: none"> • „Hands-on“ stations • Topic: Bionics in the water • Different aspects of bionics directly on the compound • Integration of the new exhibition "IdeenreichNatur"
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7. Learning Science Through Theater - NKUA's contribution

<p>Learning environments(physical and computational media involved)</p>	<ul style="list-style-type: none"> ➤ Classroom ➤ Theater stage ➤ National Center for Scientific Research "Demokritos", ➤ ATLAS or CMS Control Centre
<p>Characteristics of learning environments</p>	<ul style="list-style-type: none"> ➤ Pluralities, possibilities, participation, playfulness (Craft, 2011) ➤ Individual, collaborative and communal activities for change ➤ Risk, immersion and play ➤ Dialogue ➤ Interrelationship of different ways of thinking and knowing ➤ Discipline knowledge ➤ Ethics and trusteeship ➤ Importance of materials ➤ Empowerment and agency ➤ Governance ➤ Public engagement ➤ Gender equality ➤ Science education ➤ Open access/open science ➤ Ethics ➤ Sustainability ➤ Social justice/inclusion

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8. Student Parliament - NKUA's contribution

<p>Learning environments(physical and computational media involved)</p>	<p>Formal and Informal learning settings</p> <ul style="list-style-type: none"> ➤ Classroom ➤ Venue for final debate event ➤ Research center (physical visit or virtual) ➤ Open Discovery Space
<p>Characteristics of learning environments</p>	<ul style="list-style-type: none"> ✓ Governance ✓ Public engagement ✓ Gender equality ✓ Science education ✓ Open access ✓ Ethics ✓ Sustainability ✓ Social justice ✓ Observe Classroom Dynamics ✓ Personalize Large Classes ✓ Shift from a Competitive to a Cooperative Educational Model ✓ Consider a Variety of Examination Options ✓ Foster Self-Confidence
<p>Bibliography on effective learning environments</p>	<p>Baker, M.J. (1999). Argumentation and Constructive Interaction. In G. Rijlaarsdam& E. Espéret (Series Eds.) & Pierre Coirier and Jerry Andriessen (Vol. Eds.) <i>Studies in Writing: Vol. 5. Foundations of Argumentative Text Processing</i>, 179-202. Amsterdam: University of Amsterdam Press</p> <p>Burris, J. E. (2012). It's the teachers. <i>Science, 335</i>, 146.</p> <p>Conole, G.; Fill, K. (2005). A learning design toolkit to create pedagogically effective learning activities. In <i>Journal of In-teractive Media in Education, 8 (1)</i>.</p>

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9. Introducing the Ghost particles- NKUA's contribution

<p>Learning environments(physical and computational media involved)</p>	<ul style="list-style-type: none"> ➤ Classroom ➤ PC labs (computer models and simulations) ➤ Virtual labs (Cern) ➤ WIPAC (video demonstrator)
<p>Characteristics of learning environments</p>	<ul style="list-style-type: none"> ➤ Inquiry-based Science education ➤ Personal engagement and hands-on experimentation through interactive simulating environments (computer simulations, logo based or based on Flash or Unity) ➤ Combination of art and Science
<p>Bibliography on effective learning environments</p>	<ul style="list-style-type: none"> ➤ Pedaste, M. et al (2015): Phases of inquiry based learning: Definitions and the inquiry cycle. <i>Educational research review</i>. DOI 10.1016/j.edurev.2015.02.003 ➤ Kynigos, C. (2002a). <i>Mind Tools and Informational Media, Pedagogical Uses of New Technologies for the Development of Educational Practice</i>, Athens: Kastaniotis

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10.Science & Art@School - CERN's contribution

<p>Learning environments (physical and computational media involved)</p>	<ul style="list-style-type: none"> ➤ School/classroom ➤ Science center (physically or through virtual visit) ➤ Museum or art space ➤ Science festival
<p>Characteristics of learning environments</p>	<ul style="list-style-type: none"> ➤ Interdisciplinarity ➤ Dialogue ➤ Collaborative and communal activities ➤ Balance and navigation ➤ Empowerment and agency ➤ Risk, immersion and play ➤ Possibilities ➤ Ethics and trusteeship ➤ Open and responsible science

	<ul style="list-style-type: none"> ➤ Public engagement and communication ➤ Social inclusion and impact
Bibliography on effective learning environments	<p>a) Conference presentations: EPS High Energy Physics 2015 Conference, Vienna, 22-29 July</p> <p>b) Conferencepapers: Alexopoulos, A. et al. (2015) Resources for Education and Outreach Activities: Discussion Session. The European Physical Society Conference on High Energy Physics, Vienna, 22-29 July.[available at http://cds.cern.ch/record/2132291/files/ATL-OREACH-PROC-2016-002.pdf]</p> <p>Hoch, M. &Alexopoulos, A. (2014) ART@CMS and SCIENCE&ART@SCHOOL: Novel Education and Communication Channels for Particle Physics. Proceedings of the the 14th ICATPP Conference, Vol. 1, 728-736. [available at http://adsabs.harvard.edu/abs/2014apsp.conf..728H]</p>

2.3 Resulting Learning Environments Categorization

Considering all key elements and aspects that would enable and ensure the development of learning environments that are efficient in addressing creativity-enriched inquiry in science teaching, the following 7 types of learning environments have been identified:

1. **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.
2. **Simulations** aiming to enable the visualization of theoretical models and facilitate inquiry-based experimentation
3. **Arts-based** which addresses and enhances scientific interconnection of science with aspects of art
4. **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

5. **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.
6. **Visits to research centres (virtual/physical)** aiming to connect the science classroom with research infrastructures, addressing the enhancement of informal learning settings.
7. **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'.

Although these types of learning environments formulate concrete areas for approaching creativity-enriched inquiry they are structured in a flexible and interlapping way which allows for multiple entries and exploitations.

2.4 Generic Learning Environments template

Type of Learning Environments	Description	Characteristics	Indicative examples
1. Communities of practice (web-based/physical)	<p>Developing a network of online communities and channels sharing multicast-activities inspired by science on national or international level.</p> <p>They rely on the facilitation and empowering of a democratic process in that all participants recognize their own inputs in the final, collaborative whole, thus providing a dialogue of respect for other participants' creative ideas. They act as learning resources repositories where practitioners may find innovative proposals to improve their educational practice. The community's assessment role in ensuring information on the resources quality and the congruence of the metadata standards with the current indications of the learning theories (Mayes and Fowler, 1999).</p> <p>The core group of this community (teachers acting as change agents) will act as a central dissemination channel introducing the CREATIONS approach to their colleagues, head of the school, curriculum developers, parents and others involved</p>	<ul style="list-style-type: none"> • Interrelationship of different ways of thinking and knowing • Pluralities, possibilities, participation, playfulness (Craft, 2011) • Individual, collaborative and communal activities for change • Dialogue • Public engagement • Sustainability • Social justice/inclusion • Interactive engagement • Developing a cross-country, multi-cultural spirit of friendship, cooperation and teamwork • Digital competences and their social impacts • Collaborative, creative and flexible process, including elements which cannot be foreseen in advance • Democratic process in which you learn from, others' creative ideas. • Collective idea generation and a solution- finding process which is dialogic in nature. 	<p>Eg. Global Science Opera Real Time (GSort)</p>

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	<p>in the broad field of education of students at their school. Involved and new attracted teachers will form communities of practitioners of creativity-enriched inquiry which enable teachers to learn from each other.</p>		
<p>2. Simulations</p>	<p>Visualizing theoretical models and the development of activities that:</p> <ul style="list-style-type: none"> • explore and manipulate models aimed at developing knowledge of their characteristics and adopting the rules that govern their function; • lead to modelling, i.e. using ICT tools to develop models of physical phenomena. (Hucke and Fischer, 2002; Buty, 2003; Beaufils and Richoux, 2003; Niedderer et al., 2002; Goldberg and Otero, 2001; Zacharia, 2003; Smyrniou and Weil-Barais, 2005; Smyrniou et al., 2012a; Smyrniou et al., 2012b; Somekh and Davis, 1997). 	<ul style="list-style-type: none"> • Open access/open science • Interactive engagement • Reflects the constructivist model of learning • Related to the nature of science including inquiry knowledge and skills • In knowledge of contemporary science and recent advances in scientific research • Related to self-reflection and meta-cognition • Active participation in the discovery of scientific concepts • Hands-on experience • Emulation of cutting edge research work • Involvement in high end scientific data analysis • Inquiry Based Science Learning (IBSE) • Expand the resources for teaching and learning in schools and classrooms, • Provide more challenging, authentic and higher-order learning experiences for students • Encourage theoretical reflection • Act as a “cognitive bridge” between theory and practical experience • Bring into the classroom activities that are based on real-world problems 	<p>Eg the Large Hadron Collider (LHC) game, authoring tools</p>



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		<ul style="list-style-type: none"> • Provide tools and scaffolds that enhance learning • Support thinking and problem solving • Model activities and guide practice, • Represent data in different ways • Students evaluate the quality of their own thinking and products, for feedback, reflection, and revision • Be able to see patterns, connections, and relationships forming around the new concepts or physical phenomena under investigation • Be able to arrange information and collected data in a useful and consistent manner • Be able to understand the process of work and break it down to multiple steps • Act as a “cognitive bridge” between theory and practical experience 	
<p>3. Arts-based</p>	<p>Scientific interconnection of science with aspects of art: participants will undergo a multi-disciplinary artistic process which demonstrates and deepens understanding, supporting discipline knowledge in both the science and arts educational disciplines.</p> <p>(Craft, et al., 2014; Peinado, et al., 2015; Trowsdale, 2014;2016 ; Trowsdale and Challis, 2015 ; Garoian, & Mathews, 1996 ; Craft, 2011; Ben-Horin, 2014; Ben-Horin and Stergiopoulos, 2015; Smyrniou et al, 2016).</p>	<ul style="list-style-type: none"> • Research and drama activities to feed commitment and understanding of challenge • Idea generation developed by collaborative sketching and rough model making • Responsibility • Embodied learning about how forces effect structure building, • Collaborative learning, • Scientific method • Interdisciplinary practice/ transdisciplinary character • Active participation in creating live performances including music, drama and audiovisual elements inspired by scientific concepts 	<p>Eg. WASO, Science Theatre</p>



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		<ul style="list-style-type: none"> •Sharing activities through live interaction •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 •Science inquiry in a creative framework •Science communication •Artistic teamwork •Inquiry-based arts-infused process •Documentation of science learning outcomes •Active participation in the negotiation of scientific concepts •Developing creative and critical skills •Understanding of scientific concepts and phenomena •Science communication to inspire a multi-disciplinary artistic project. •Inspire a creative process in a school •Meaning Generation: Pupils directly connect their movement, gesture and communication with scientific concepts which they perceive, as embedded in the educational activities •Embodied Learning: the student can utilize his body as a source of knowledge. It enhances cognitive representations. physical representation of transfer 	
<p>4. Dialogic space / argumentation</p>	<p>Dialogic and argumentation skills deployed in the context of socio-scientific debates, which are also regarded as an opportunity to</p>	<ul style="list-style-type: none"> •Engaging students in argumentation processes for a better insight into the nature of scientific enquiry and the ways in which scientists work 	<p>Eg. Student parliament</p>



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	<p>acquire a conceptual and epistemological understanding of science.</p> <p>(Sadler, and Zeidler, 2005, Bell and Lederman, 2003; Simmoneaux, 2003; Grace and Ratcliffe, 2002; Zohar and Nemet, 2002; Mortimer and Scott, 2003; Smyrnaiou, et al., 20015).</p>	<ul style="list-style-type: none"> •Immersing learners in active investigations of contemporary issues •Engaging them in collaborative discourse •Constructively building on each other's ideas and enhancing the learning of scientific concepts •Communicating ideas with scientific experts •Improving pupils' enjoyment of and attainment in science via open-ended investigations. •Testing and exploring possible answers to scientific questions •Related to real life •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) •Developing spirit of cooperation and teamwork • Promoting conceptual development •Allowing for interdisciplinary approach and integration of enhancing texhniques (eg CLIL) 	
<p>5. Experimentation (Science</p>	<p>Create learning environments which allow students to interact physically and</p>	<ul style="list-style-type: none"> •Interactions characterised by equality and respect for children as apprentices and creators 	<p>Eg. Imagineerium project</p>



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<p>laboratories and eScience applications)</p>	<p>intellectually with instructional materials through 'hands-on' experimentation and 'minds-on' reflection.</p> <p>Effort should be made to provide materials and instruction that give reality and concreteness to scientific concepts. According to modern pedagogy, teaching should be guided by a holistic planning process that takes the students' learning processes, the subject matter and the teaching methods into account. The teaching sequences should build up in a way that student knowledge can increase and link, in other words be "constructed" by them. teaching and learning in science is successful, if it is possible to realize a sequence of topics that equally guarantee a systematic learning (vertical knowledge transfer) and situation-orientated learning with everyday tasks and problems (horizontal knowledge transfer).</p> <p>(Koballa and Groeber, 2001; Abd-El-Khalick, and Lederman, 2000; Windschitl, 2003; Jenkins, 1999; Haigh, and Forret, 2005)</p>	<ul style="list-style-type: none"> •Experiential and practical pedagogies: embodied learning, testing how the mechanisms to be used feel and work in the body; practical / hands-on problem solving with materials and in mastering techniques •Connection of experimentation with the real world •Development of life-management skills •Creative experimentation •Gathering, visualizing, and reporting data and findings •Ideas become linked and tested through the learner's experiences •Students interact with materials or with secondary sources of data to observe and understand the natural world •Engaging, hands-on experience designed to meet the interests of young people. •Competences developed: (a) identify scientific issues, (b) explain phenomena scientifically and (c) use scientific evidence •Providing a richer and more diverse picture of what is involved in doing science •Giving more autonomy to students: developing activities of a higher cognitive level. 	
<p>6. Visits to research centres (virtual/physical)</p>	<p>Connecting the science classroom with research infrastructures</p>	<ul style="list-style-type: none"> •Open access/open science •Interactive engagement •In knowledge of contemporary science and recent 	<p>Eg. Virtual Visits to ATLAS and CMS at</p>



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		<p>advances in scientific research</p> <ul style="list-style-type: none"> • Emulation of cutting edge research work • Involvement in high end scientific data analysis • Inquiry Based Science Learning (IBSE) • expand the resources for teaching and learning in schools and classrooms, • Provide more challenging, authentic and higher-order learning experiences for students • Act as a “cognitive bridge” between theory and practical experience • Bring into the classroom activities that are based on real-world problems • Model activities and guide practice, • Be able to understand the process of work and break it down to multiple steps • Act as a “cognitive bridge” between theory and practical experience 	CERN, Bionics project
<p>7. Communication of scientific ideas to audience</p>	<p>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.)</p>	<ul style="list-style-type: none"> • Development of self-esteem and life-management skills. • Immersing learners in active investigations of contemporary issues • Engaging learners in collaborative discourse • Constructively building on each other's ideas and enhancing the learning of scientific concepts • Communicating ideas with scientific experts • Improving pupils' enjoyment of and attainment in science via open-ended investigations. • Testing and exploring possible answers to scientific 	Eg science cafes, SPs



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- questions
- Related to real life
 - Active participation and engagement in the negotiation of scientific concepts
 - Developing creative and critical skills
 - Connecting science with aspects of their everyday life
 - Promoting conceptual development



3 Learning Environments' expansibility and potential

The Creations Learning Environments will act as a hub to enable the development of Educational and Outreach Activities in the form of CREATIONS Demonstrators that will be produced as a communal contribution and rich in expertise regarding the consortium. In this section we aim to demonstrate the way for the expansion and unification of the existing tools and on-line materials in the form of Initiatives at first – and expanded as Demonstrators that will be developed to provide stakeholders with unique educational resources as a source of reference and inspiration for future contributions. In the Creations framework, the learning environments repository nature will not be transmitted in a theoretical way but rather in an experiential way in the form of a real life experience. The communicative and creative element guiding the structuring of these learning environments created an interactive user experience facilitating inspiration that works both ways.

3.1 Expansion and content of the CREATIONS Learning Environments

Implementation Setting	INITIATIVES/tools	Description of initiative/tool
1. Communities of practice (web-based/physical)		
a) school based	<p><u>Global Science Opera in Real Time (GSOrt) (EA)</u></p> <p>“Let Us Share The Music” (a multiple-site link-practice)</p>	<p>Global Science Opera Real Time (GSOrt) is a community of European remote and rural schools working together in creating a distributed online-performance event based mainly on the scientific-research data coming from the particle accelerator at CERN. Primary and secondary education remote pupils participate in the planning, preparation and implementation of a video-recorded / live-multicasted artistic web-event. Long-term objective is to set the foundations for a global network of remote and rural educational communities, working in advanced-interaction technologies that promote Art, Performance and Science as a common ground for creative practices.</p>

	<p><u>Learning Science Through Theater – LSTT (NKUA)</u></p>	<p>Learning Science Through Theatre is designed as a transversal meeting point between preparing and staging a play and an Inquiry-Based Science Education model. It follows a scientific approach while opening doors to experiencing new possibilities on several levels. As part of the exploration towards the play's creation, students are asked to dramatize scientific concepts and knowledge from the curriculum of their courses. The initiative is based on the pedagogical framework developed by the European Project CREAT-IT and the principles of Inquiry Based Science Education (IBSE). Students are also provided with open access to research centers in order to use up-to-date information of science.</p>
<p>b) school – research center collaboration</p>	<p><u>Global Science Opera in Real Time (GSOrt) (EA)</u></p>	
	<p><u>Learning Science Through Theater – LSTT (NKUA)</u></p>	
<p>c) professional development</p>	<p><u>Global Science Opera in Real Time (GSOrt) (EA)</u></p> <p>“Let Us Share The Music” (a multiple-site link-practice)</p>	
<p>2. Simulations (digital/physical)</p>		
<p>a) school based</p>	<p>The Imagineerium (EXETER)</p> <p>CAD (Design123) software</p>	<p>The Imagineerium project is an imaginative frame, performed by artists, which draws pupils in to a 'commission' to work with 'Imagineers' (performers, artists designers and engineers). This is to work in groups to imagine, design and make a model of an animated, mechanical vehicle for a real performance event. One of the</p>

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		<p>models is selected then built full scale and performed at a regional cultural festival or event. The project takes place both within the school and the Imagineerium space – a disused (but historically significant) engineering space adapted temporarily as an arts creation space.</p>
	<p><u>Engaging students in High Energy Physics HYPATIA (IASA)</u></p>	<p>HYPATIA is an event analysis tool for data collected by the ATLAS experiment of the LHC at CERN. Its goal is to allow high school and university students to visualize the complexity of the hadron - hadron interactions through the graphical representation of ATLAS event data and interact with them in order to study different aspects of the fundamental building blocks of nature.</p> <p>HYPATIA can be used on most modern operating systems such as Windows, Linux, Unix, Solaris, MacOS etc. The graphical representation (canvas) ensures very accurate and detailed display of the event tracks. The canvas allows even inexperienced users to interact with the events using simple point-and-click functionality. The multiple views of the ATLAS detector that are available ensure that the user will get an accurate view of all the particle tracks that make up an event.</p>
	<p><u>Introducing the Ghost particles (NKUA)</u></p>	<p>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 physics research – "The Ghost Particles, neutrinos". Nobel prize winning in physics for 2015.</p> <p>The main goal of the specific initiative is to incorporate a series of activities which will allow</p>

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		<p>us to create an engaging learning environment in classroom.</p> <p>The initiative involves Interactive computer simulations, logo based or based on Flash or Unity, half-baked microworlds (Kynigos, 2012), videos and virtual visits (Cern and Wipac), games, role playing, and creative artistic mediation (drawings, posters, comics and 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.</p>
	<p>Science&Art@School (CERN)</p>	<p>Science&Art@School promotes the idea that particle physicists and artists share fertile common ground in their parallel efforts to understand <i>physis</i> (the Greek word for <i>nature</i>).</p> <p>Science&Art@School takes the art@CMS concept a step further by bringing second-level students from the arts and science curricula together with CMS scientists, science educators and art educators during extended learning periods with the aim to help students:</p> <ul style="list-style-type: none"> • Understand how scientific research in high energy physics at CMS and CERN works • explore how CMS researchers and artists work and view each other's world • engage in and create artistic works inspired by the big physics questions driving scientific work at CMS and CERN, and develop positive attitudes towards science and technology related work at large research infrastructures like CMS

		and CERN.
b) school – research center collaboration	The Imagineerium (EXETER)	
	<u>Engaging students in High Energy Physics HYPATIA (IASA)</u>	
	<u>Introducing the Ghost particles (NKUA)</u>	
	Science&Art@School (CERN)	
c) professional development	<u>Introducing the Ghost particles (NKUA)</u>	
3. Arts-based		
a) school based	The Imagineerium (EXETER)	
	Global Science Opera in Real Time (GSOrt) (EA/HSH)	
	Write a Science Opera (WASO) (HSH)	
	<u>Learning Science Through Theater – LSTT (NKUA)</u>	
	<u>Introducing the Ghost particles (NKUA)</u>	

	Science&Art@School (CERN)	
b) school – research center collaboration	The Imagineerium (EXETER)	
	<u>Global Science Opera in Real Time (GSOrt) (EA)</u> "Let Us Share The Music" (a multiple-site link-practice)	
	Write a Science Opera (WASO) (HSH)	
	<u>Learning Science Through Theater – LSTT (NKUA)</u>	
	Science&Art@School (CERN)	
c) professional development	<u>Global Science Opera in Real Time (GSOrt) (EA)</u> "Let Us Share The Music" (a multiple-site link-practice)	
	Write a Science Opera (WASO) (HSH)	
4. Dialogic space/argumentation		
a) school based	<u>Global Science Opera in Real Time</u>	

	<p><u>(GSOrt) (EA)</u></p> <p>“Let Us Share The Music” (a multiple-site link-practice)</p>	
	<p>Student Parliament – SP (NKUA)</p>	<p>The SP’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”.</p>
b) school – research center collaboration	<p><u>Global Science Opera in Real Time (GSOrt) (EA)</u></p> <p>“Let Us Share The Music” (a multiple-site link-practice)</p>	
	<p>Student Parliament – SP (NKUA)</p>	
c) professional development	<p><u>Global Science Opera in Real Time (GSOrt) (EA)</u></p> <p>“Let Us Share The Music” (a multiple-site link-practice)</p>	
<p>5. Experimentation</p>		
a) school based	<p>The Imagineerium (EXETER)</p>	
b) school – research center	<p>The Imagineerium (EXETER)</p>	

collaboration		
c) professional development		
6. Visits to research centres (virtual/physical)		
a) school based	<u>Engaging students in High Energy Physics HYPATIA (IASA)</u>	
	<u>Learning Science Through Theater – LSTT (NKUA)</u>	
	<u>Bionics – out-of-school learning in the zoo (UBT)</u>	<p>In cooperation with the “BIONICUM” at the zoo in Nuremberg a curriculum compliant learning circle about Bionics was established (6th grade).</p> <p>The intervention provides selected bases around the theme of bionics and their diversity.</p> <p>Students gain an overview about different bionic areas and learn the bionics concept and its importance to know.</p>
	<u>Introducing the Ghost particles (NKUA)</u>	
	Science&Art@School (CERN)	
b) school – research center collaboration	<u>Engaging students in High Energy Physics HYPATIA (IASA)</u>	
	<u>Learning Science Through Theater – LSTT (NKUA)</u>	
	<u>Bionics – out-of-school learning in</u>	

	<u>the zoo (UBT)</u>	
	<u>Introducing the Ghost particles (NKUA)</u>	
	Science&Art@School (CERN)	
c) professional development		

7. Communication of scientific ideas to audience

a) school based	The Imagineerium (EXETER)	
	<u>Global Science Opera in Real Time (GSOrt) (EA)</u> "Let Us Share The Music" (a multiple-site link-practice)	
	Student Parliament – SP (NKUA)	
b) school – research center collaboration	The Imagineerium (EXETER)	
	<u>Global Science Opera in Real Time (GSOrt) (EA)</u> "Let Us Share The Music" (a multiple-site link-practice)	
	Student Parliament – SP (NKUA)	
c) professional	<u>Global Science</u>	

development

Opera in Real Time (GSOrt) (EA)

“Let Us Share The Music” (a multiple-site link-practice)



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5 ANNEXES

5.1 ANNEX A

Pro-forma table designed by NKUA to request partners' contribution in the identification of the CREATIONS Learning Environments and their underlying characteristics as well as partners' inputs on the context and structuring of the CREATIONS Initiatives.

Task 2.3 Designing Effective Learning Environments that Support Creativity in Inquiry (Responsible NKUA)

Initiatives' structure and Effective learning environments

Initiatives' structure and Effective learning environments	
Title of the Initiative	
Summary	
Settings (a) school based, b) school – research center collaboration, c) professional development)	
Final outputs	Eg. Science Debate, science café, Science theater, ICT creative output, etc.
Aims / Educational objectives:	<ul style="list-style-type: none"> ➤ 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
Learning environments(physical and computational media involved)	
Characteristics of learning environments	
Description of the additional pedagogical framing of the initiative	Eg. constructionism, argumentation approach, CCL, etc.
Description of the main activities	

D2.3 Effective learning environments for inquiry learning and teaching

Methods of learning/ training	Eg. Inquiry, experimentation, collaborative learning, scientific method, discussion, etc.
End user (depending on the category: school based, school – research center collaboration, professional development)	
Involved actors	
Location	
Connection with the curriculum	
Evaluation parameters	
Additional resources	
Users'/Developers' Required competences	<ul style="list-style-type: none"> ✓ related to the nature of science including inquiry knowledge and skills ✓ in framing a discipline in a multidisciplinary scenario ✓ in knowledge of contemporary science ✓ in mastering and implementing a variety of instructional strategies ✓ in sustaining autonomous life-long learning ✓ related to self-reflection and meta-cognition ✓ related to the area of teaching/learning processes within the domain ✓ in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students ✓ addressing students' common sense knowledge and learning difficulties ✓ in the use of ICTs ✓ in the knowledge, planning and use of curricular materials
Bibliography on a) effective learning environments and b) initiatives	

5.2 ANNEX B

Partners' contributions

1. EA's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	<u>Global Science Opera in Real Time (GSOrt)</u>
Summary	<p>Global Science Opera Real Time (GSOrt) is a community of European remote and rural schools working together in creating a distributed online-performance event based mainly on the scientific-research data coming from the particle accelerator at CERN.</p> <p>Primary and secondary education remote pupils participate in the planning, preparation and implementation of a video-recorded / live-multicasted artistic web-event, following the educational standards of CREATIONS project and the Global-Science-Opera practice as it was developed under CREAT-IT project. Activities of this community will form one scene of the Global Science Opera supporting the goals of the project.</p> <p>Long-term objective is to set the foundations for a global network of remote and rural educational communities, working in advanced-interaction technologies that promote Art, Performance and Science as a common ground for creative practices.</p>
Settings (a) school based, b) school – research center collaboration, c) professional development)	<ul style="list-style-type: none"> ➤ School Based with ICT & teleconference support ➤ School- Art@CMS / CERN collaboration
Final outputs	<p>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.</p>
Aims / Educational objectives:	<ul style="list-style-type: none"> ➤ Active participation in creating live performances including music, drama and audiovisual elements inspired by scientific concepts ➤ Sharing activities through live interaction using teleconference or any other real time interaction environment ➤ Developing skills of artistic teamwork between remote/rural and non-remote/rural schools through peer-tutoring methods supervised by teachers. ➤ 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. ➤ Using synchronous-communication ICT solutions in implementing WASO, Science-Theatre and Science-Café case-study practices according to their corresponding guidelines developed by CREATIT project.

	<p>More Specifically:</p> <ul style="list-style-type: none"> • Pupils in remote schools will learn the principles of basic science concepts beyond the school curriculum by enhancing the idea of contributing into an online performance with other schools preparing its content according to the IBSE phases. • "Let Us Share The Music" is a multiple-site link-practice in which all participants (remote sites) collaborate with each other in order to create and perform a music web event. The scenario of this action is selected and registered as "good-practice" by the Greek Pedagogical Institute as part of the Major Teacher's Training Program • The initiative aims to make remote and rural educational communities understand the effects of Science in various Art sectors and to critically face their use to estimate future impacts on themselves and society.
<p>Learning environments(physical and computational media involved)</p>	<ul style="list-style-type: none"> ➤ A customized videoconference environment serves as a live online stage shared by schools collaborating with each other in order to create a live audiovisual web-event.
<p>Characteristics of learning environments</p>	<p>The characteristics cover nearly all aspects of the project's pedagogical principles such as</p> <ul style="list-style-type: none"> ➤ Interrelationship of different ways of thinking and knowing ➤ Pluralities, possibilities, participation, playfulness (Craft, 2011) ➤ Individual, collaborative and communal activities for change ➤ Risk, immersion and play ➤ Dialogue ➤ Public engagement ➤ Sustainability ➤ Social justice/inclusion ➤ Interactive engagement
<p>Description of the additional pedagogical framing of the initiative</p>	<ul style="list-style-type: none"> ➤ Inquiry Based Learning: reflects the constructivist model of learning, often referred to as active learning ➤ "Let Us Share The Music" is a multiple-site-link practice in which all participants (remote sites) collaborate with each other in order to create and perform a live music web event. A configurable multicast videoconference platform supports the initiative. ➤ The pedagogical framing of the GSOrt learning environment is fully compatible with GSO and LSTT2 initiatives.
<p>Description of the main activities</p>	<p>There are numerous possibilities in engaging all ages of students in Performance Arts/IBSE activities, a major part of them being described thoroughly through the case-study guidelines and scenarios of the CREATIT project.</p> <p>GSOrt initiative is focused upon the exploitation of WASO and ST case-studies in Real-Time collaborative environments with remote schools in</p>

teaching elements of the Science curriculum by promoting Music creation as a live performance art. GSOrt follows a 6-phase sequence based upon the "Let Us Share The Music" good practice (Greek Ministry of Education, Major Teacher's Training Program), including the IBSE 5-phase sequence as part of it.

Numbers of sessions correspond to videoconference meetings.

Phase A: Initial Planning (1-2 sessions)

During this phase, 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.

Phase B: Preparation of the interactive practice and material (1-3 sessions)

a) Teachers prepare a draft of the interactive scene by mutually agree on their roles of performance and contribution. This includes a summary of the 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.

b) Students are introduced to the idea of participating in an online interactive event with distant communities. The 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 Phase 1: Question Eliciting Activities/Exhibiting Curiosity (videos, discussion etc) and Phase 2: 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 C: Finalization of the Scene and First draft of the Link Scenario (2-3 sessions)

a) Teachers finalize the scene according to the process of the previous phase and circulate the first draft of the Link Scenario. Advanced features of the platform are introduced in order to serve interaction possibilities

	<p>triggered by participants.</p> <p>b) Students are assigned the preparation of the scene-content and the local rehearsals, according to the above phase. This corresponds to IBSE Phase 3: Creation. The virtual stage environment is available for online rehearsals if necessary.</p> <p>Phase D: Finalization of the Link Scenario and implementation within with the virtual stage (1 session)</p> <p>a) Teachers introduce the local student-teams online. The first implementation of the Link scenario takes place live. Each team performs adjustments.</p> <p>b) Remote students are introduced online and perform their roles at the scene according to the Link Scenario.</p> <p>Phase E: Rehearsals according to the Link Scenario (2-4 sessions)</p> <p>a) Teachers perform the final adjustments taking in account the previous phase and after discussing with their students (and with the teachers of the other teams if necessary). Link Scenario is locked and teachers supervise the online rehearsals according to the adapted schedule.</p> <p>b) 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. This corresponds to IBSE Phase 4: Discussion.</p> <p>Phase F: Final Performance (2 sessions) The final online performance takes place in order to be recorded or broadcasted. After the final performance students remain online to exchange virtual cart-postals with thoughts, ideas, pictures, or "best of" material online in ppt form. 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. This phase corresponds to IBSE Phase 5: Reflection.</p>
Methods of learning/ training	Inquiry Based Science Learning (IBSE) including the necessary different phases (Introduction, Perform investigation, Results and Discussion)
End user (depending on the category: school based, school – research center collaboration, professional development)	Students of all ages supported by their teachers.
Involved actors	<ul style="list-style-type: none"> ➤ Teachers ➤ Students ➤ Researchers ➤ Artists/ Art-teachers ➤ Performance-Art teachers ➤ Scientific collaborators from University

D2.3 Effective learning environments for inquiry learning and teaching

Location	<ul style="list-style-type: none"> ➤ Classroom with the support of WiFi or ADSL connection ➤ Theatre with the support of WiFi or ADSL connection ➤ Outdoor environment with the support of WiFi (or ADSL connection)
Connection with the curriculum	All developing scenarios are supported through the so called “flexible zone” at least in Greece.
Evaluation parameters	<ul style="list-style-type: none"> ➤ Teachers participate on online and focus-group sessions requested by the GSOrt manager depending on the needs of the project. All data requested by national implementation leaders is provided through online forms or teleconference-interviews with the contributors.
Additional resources	<ul style="list-style-type: none"> ➤ http://connect.ea.gr ➤ http://www.opendiscoveryspace.eu/community/global-science-opera-real-time-835933 ➤ http://www.opendiscoveryspace.eu/community/gsort-gr-pagkosmia-opera-epistimis-elliniki-koinotita-837837 ➤ http://dma.ea.gr/ ➤ http://portal.opendiscoveryspace.eu/community/moirastoyme-ti-moysiki-enosoyme-ton-kosmo-let-us-share-music-let-us-link-world-347 ➤ http://portal.opendiscoveryspace.eu/el/node/820734 ➤ http://www.opendiscoveryspace.eu/topic-courses/live-music-education-academy
Users’/Developers’ Required competences	<ul style="list-style-type: none"> ➤ Intermediate computer usage skills ➤ Basic understanding of music elements ➤ Sufficient management of audio/video computer-properties ➤ Interest in the relation between the Arts and the Sciences
Bibliography on a) effective learning environments and b) initiatives	<ul style="list-style-type: none"> ➤ Prof. Anna Craft, Oded Ben Horin, MenelaosSotiriou, PetrosStergiopoulos, Dr. SofoklisSotiriou, Sarah Hennessy, Dr. Kerry Chappell, Charlotte Slade, Dr. Margo Greenwood, Dr Alison Black, DobrivojeLaleErić, ĐurđaTimotijević, Aleksandra Drecun, Ana Brajović, Cinzia Belmonte, Giovanna Conforto (2014). CREAT-IT: Implementing Creative strategies into Science Teaching. Proceedings of the 1st International Conference on New Developments in Science and Technology Education, <i>Book of abstracts (pp. 37-38)</i>. ➤ Sonia PEINADO, José Miguel MOTA, Anke BERNES, Manuel PALOMO-DUARTE, Juan Manuel DODERO, Stefano MARTELLLOS, Rosa DORAN, Aušra LINGYTE, Christine J. ARNOLD, Kerstin BISSINGER, Orlin KOUZOV, Eleni CHELIOTI, Stephanos CHEROUVIS, Petros STERGIOPOULOS (2015). Experiences of technology-rich innovation in European schools within the Open Discovery Space project. Education in The Knowledge Society, journal.

2. EXETER's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	The Imagineerium
Summary	In the Imagineerium project, an imaginative frame, performed by artists, draws pupils in to a 'commission' to work with 'Imagineers' (performers, artists designers and engineers). This is to work in groups to imagine, design and make a model of an animated, mechanical vehicle for a real performance event. One of the models is selected then built full scale and performed at a regional cultural festival or event. The project takes place both within the school and the Imagineerium space – a disused (but historically significant) engineering space adapted temporarily as an arts creation space.
Settings (a) school based, b) school – research center collaboration, c) professional development)	a) and b.)
Final outputs	Creative output: scaled models of engineered vehicle ideas are made and pitched to audience; after a selection process, one is made to full-size Presentations to pitch ideas, often with performative elements to articulate ideas for performance effect.
Aims / Educational objectives:	<ul style="list-style-type: none"> ➤ 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
Learning environments(physical and computational media involved)	Classroom: altered and evolving in bespoke ways to provoke responses to the tasks and encourage attention to learning capacities required e.g. collaboration (support, challenge, role, responsibility); perseverance (thinking in different ways, being resourceful, being open to new ideas and trying them out) Professional maker space / creation centre, with materials and tools for experimenting / making CAD (Design123) software
Characteristics of learning environments	Messy, full of colour, found / recycled materials / soft and hard textures, workbenches, tools ... biscuit and drinks hub.

D2.3 Effective learning environments for inquiry learning and teaching

	Interactions characterised by equality and respect for children as apprentices and creators Experiential and practical pedagogies: embodied learning, testing how the mechanisms to be used feel and work in the body; practical / hands-on problem solving with materials and in mastering techniques
Description of the additional pedagogical framing of the initiative	Imaginative, real world (commission)
Description of the main activities	Research and drama activities to feed commitment and understanding of challenge; idea generation developed by collaborative sketching and rough model making; responsibility; embodied learning about how forces effect structure building, mechanisms, mechanical advantage.
Methods of learning/ training	Experimentation, collaborative learning, scientific method, discussion, apprenticeship
End user (depending on the category: school based, school – research center collaboration, professional development)	Children, Imagineer engineers and adults, and the public
Involved actors	Young people aged 8-10 and 16-25 Artists: Performers, designers, engineers, educators, STEM ambassadors, engineering technology (CAD) students
Location	Coventry, England
Connection with the curriculum	National Curriculum Year 5 Physical sciences; Design and Technology, Mathematics, Writing Possibility for application into Year 4 and 6 too. It has also been used with older students.
Evaluation parameters	The project will be evaluated with all 8-10 year olds in terms of a.) English, Science, Maths and Design and Technology achievement before and after b.) self evaluation of evidence of skill / capability development in terms of and team-working and perseverance c.) perceptions about the arts and sciences through the frame of Imagineering as a compound / interdisciplinary practice With older students aged 16-25 whilst the same areas will be reviewed, the focus will be upon the development of self-esteem and life-management skills.
Additional resources	Imagineers (professional artists, designers and engineers) Imagineerium resources: re-cycled and found resources; tools; space STEM ambassadors, University design and engineering students Local industry partners CAD Design 123
Users'/Developers' Required competences	✓ related to the nature of science including inquiry knowledge and skills ✓ in framing a discipline in a multidisciplinary scenario

D2.3 Effective learning environments for inquiry learning and teaching

	<ul style="list-style-type: none"> ✓ in knowledge of contemporary science ✓ in mastering and implementing a variety of instructional strategies ✓ related to self-reflection and meta-cognition ✓ related to the area of teaching/learning processes within the domain ✓ in using projects, modeling and outdoor activities to build understanding and skills of students ✓ addressing students' common sense knowledge and learning difficulties ✓ in the use of ICTs ✓ in the knowledge, planning and use of curricular materials
<p>Bibliography on a) effective learning environments and b) initiatives</p>	<p>Conference presentations related to the Imagineerium:</p> <ul style="list-style-type: none"> - 'Engineering the imagination? STEM learning in an arts context' by Jo Trowsdale, ECER 2014 - 'Researching Creativity Creatively' by Jo Trowsdale with Sue Challis, BERA 2015 - 'Being and Learning "like me" – developing learners through an arts and engineering partnership by Jo Trowsdale, BERA 2016 <p>Project Report: The Imagineerium Pilot Project 1 – with schools July 2014 - Jo Trowsdale with Sue Challis</p> <p>Under review:</p> <ul style="list-style-type: none"> - 'Imagineering: imagining and creating across the arts and engineering through collaborative art-making' by Jo Trowsdale in 'Creativity and Social Interactions', Special Edition of <i>Creativity: Theories, Research, Applications</i> - 'Considering the affective potential of art-making processes to foster personal relevance in science education' in 'Beyond STEM education: toward the integration of the Arts' Special edition of <i>International Journal of Science Education</i>

3. IASA's contribution

Initiatives' structure and Effective learning environments	
Title of the Initiative	<u>Engaging students in High Energy Physics</u>
Summary	<p>School curriculum in most countries includes very little (if any) material about particle physics or even modern physics in general. While established principles are essential for the students' understanding of physics, they also need to learn about recent advances in physics research.</p> <p>This is the goal of the three examples of playful learning scenarios presented below. They are designed for different ages and focus on increasingly complex concepts, all having to do with Nuclear and Particle Physics. Through these interactive exercises, which include computer games, we aim to present to the students complex principles such as the origin and meaning of mass, particle decays and subatomic structure. These function as extensions to the current school curriculum and aim to ignite the students' interest and engage them in a process of physics-based discovery.</p>
Settings (a) school based, b) school – research center collaboration, c) professional development)	<ul style="list-style-type: none"> ➤ School Based ➤ School-CERN collaboration
Final outputs	Demonstrators (including documentation of the process each school followed)
Aims / Educational objectives:	<ul style="list-style-type: none"> ➤ 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 <p>More Specifically:</p>

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	<ul style="list-style-type: none"> • 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.
Learning environments(physical and computational media involved)	<ul style="list-style-type: none"> ➤ Classroom ➤ University ➤ PC labs
Characteristics of learning environments	<ul style="list-style-type: none"> ➤ Science education ➤ Open access/open science ➤ Interactive engagement
Description of the additional pedagogical framing of the initiative	<ul style="list-style-type: none"> ➤ Inquiry Based Learning: Reflects the constructivist model of learning, often referred to as active learning. Students are encouraged to learn by discovering and trying new concepts on their own. They are given the necessary fundamental knowledge and have to apply that in order to perform the exercises and reach the optimal result. The exercises they perform are directly related to the Big Ideas of Science.
Description of the main activities	<p>There will be activities available for different age groups of students. These aim to present to them physics concepts that are suitable to their age and encourage them to explore them and discover how they apply to real world subatomic phenomena.</p> <p>For younger students (aged 9-12) the activity will include a game through which they will built up nuclei of different chemical items as well as a game which teaches them the composition of the constituents of the nuclei (protons and neutrons).</p> <p>Students between 12-15 years old can learn about particle accelerators through the "LHC game" activity. Through this, they are shown how a modern particle accelerator works, what the steps are needed in order to bring particles into collision, the challenges in building and operating them and how physicists and engineers overcome the technical difficulties in the Large Hadron Collider (LHC) at CERN. This is followed by a game where the students apply their knowledge of accelerator operation.</p> <p>The 15-18 year old students can perform data analysis of data collected from the LHC running, using the HYPATIA event analysis tool written by IASA members of the consortium and used by about 5,000 students yearly all over the world. Several scenarios for different learning emphasis have been written, based on the HYPATIA event display. The students can either learn about the traces that charged leptons leave in the ATLAS detector or re-</p>

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	discover the Z or Higgs bosons or use the curved particle tracks to measure the magnetic field of the ATLAS detector. These activities begin with lectures bridging the gap between high-school curriculum and modern physics research. The students learn about the Standard Model of physics, research being conducted at CERN and the operation of the LHC and the ATLAS particle detector. They can also tour remotely the two main experiments at LHC (CMS and ATLAS) through Virtual Visits to their Control Centers and even to the underground cavities! Then the students analyze real data looking for the previously described Z and Higgs boson decays. Finally they can compare their results to the ones published by the ATLAS experiment or with other teams from different countries during the International Masterclasses.
Methods of learning/ training	Inquiry Based Science Learning (IBSE) including the necessary different phases (Introduction, Perform investigation, Results and Discussion)
End user (depending on the category: school based, school – research center collaboration, professional development)	Students of 1 ages 9-18 (depending on the exercise)
Involved actors	<ul style="list-style-type: none"> ➤ Teachers ➤ Students ➤ Researchers ➤ Research infrastructures ➤ Scientific collaborators from University
Location	<ul style="list-style-type: none"> ➤ School Classroom ➤ University ➤ Virtual Visits to ATLAS and CMS at CERN
Connection with the curriculum	All exercises are designed as extensions to the current school curriculum at least in Greece.
Evaluation parameters	<ul style="list-style-type: none"> ➤ Students can compare the results of their analysis to the official results published by the ATLAS consortium or with the results obtained by other teams working on the same analysis
Additional resources	<ul style="list-style-type: none"> ➤ http://hypatia.iasa.gr/ ➤ http://hypatia.phys.uoa.gr/
Users' /Developers' Required competences	<ul style="list-style-type: none"> ➤ Basic computer usage skills ➤ Basic knowledge about chemical elements and building blocks of matter ➤ Understanding of electromagnetism and atomic structure for the HYPATIA exercises
Bibliography on a) effective learning environments and b) initiatives	<ul style="list-style-type: none"> ➤ S Vourakis and C Kourkouvelis, HY.P.A.T.I.A. – An Online Tool for ATLAS Event Visualization, Volos summer school 2013 proceedings ➤ Stylianos Vourakis, Bringing high energy physics to the classroom with HY.P.A.T.I.A., ICNFP Kolympari 2013, EPJ Web of Conferences 71, (2014) 00137 ➤ C Kourkouvelis and S Vourakis , HYPATIA-An online tool for ATLAS

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event visualization, IOP science Physics Education, Volume 49 Number 1, 2014 Phys. Educ. 49 21 doi:10.1088/0031-9120/49/1/21 <http://iopscience.iop.org/0031-9120/49/1/21/>

- Christine Kourkouvelis and Stylianos Vourakis on behalf of the ATLAS collaboration, How the HYPATIA analysis tool is used as a hands-on experience to introduce HEP to high schools Presented at the ICHEP 2014, Valencia, Spain, Valencia 2014, Nuclear Physics B Proceedings Supplement 00 (2014) 1–7 : 10.1016/j.nuclphysbps.2015.09.198
- C.Kourkouvelis and S.Vourakis, Introducing HEP to schools through educational scenaria, EPJ Web of Conferences 95,03021 (2015) DOI:10.1051/epfconf/20159503021
- Stylianos Vourakis, Christine Kourkouvelis and Sofoklis Sotiriou, The interactive “HYPATIA” tool as a good practice science education resource of the “Go-Lab” FP7 European project , International Conference New Perspectives in Science Education, Florence 2015, to be published in proceedings
- Dimitris Fassouliotis, Christine Kourkouvelis, Stylianos Vourakis , Introducing HEP to university students through web based simple hands-on analysis – ICNFP Kolybari 2015
- Involving students in HEP research with the help of the “Inspiring Science Education” and “Go-lab” European outreach projects – EPS 2015 Vienna
- Stylianos Vourakis, Dimitris Fassouliotis and Christine Kourkouvelis An advanced Go-Lab scenario for the GUI-based analysis of large samples of particle physics data REV 2016, Madrid
- Dimitris Fassouliotis, Christine Kourkouvelis, and Stylianos Vourakis The Inspiring Science Education project and the resources for HEP analysis by university students ICNFP 2015



4. HSH's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	Global Science Opera (GSO)
<p>Summary</p>	<p>GSO is a global, transdisciplinary creative education initiative made possible through digital interactions. GSO is a network of scientists, art institutions, schools, universities, and educational projects, 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 is the first opera initiative in history to envision, create, produce and perform educational operas by and for a global community through real-time live streaming.</p> <p>GSO produces one global science opera per year. The first opera was "SkyLight", an official initiative of UNESCO's International Year of Light.: https://www.youtube.com/watch?v=LEaB4HRHxKo</p> <p>"SkyLight" was endorsed by the International Astronomical Union. It was realized within the Write a Science Opera (WASO) initiative and the EU Comenius Project "Implementing Creative Strategies into Science Teaching (CREAT-IT)", in collaboration with additional creative learning projects, and Lunar Mission One. It was performed during World Space Week: https://www.youtube.com/watch?v=9tA-n9TR3T0.</p> <p>GSO's second production, "Ghost Particles", builds on a scientific concept provided by Dr. SofoklisSotiriou (EA, Greece). Scientific exploration will be inspired by virtual visits to art@CMS/CERN.</p> <p>The planned scientific themes for the following years' productions are (tentative):</p> <p>2017: DNA/Marine Biology</p> <p>2018: The Science of Making Peace</p>

<p>Settings (a) school based, b) school – research center collaboration, c) professional development)</p>	<p>GSO includes settings a, b, c, and others.</p> <p>It is a flat-hierarchy, homogenous network which includes high-level scientists, pupils, art institutes, policy makers, media and artists in a combined effort. Due to logistical challenges, GSO has assigned one “alpha-contact” for each country. That person was responsible for the engaging of further participants in that country. In the framework of the CREATIONS project, this may be a school, a research center, or a university.</p> <p>www.globalscienceopera.com (website will be launched in March, 2016)</p>
<p>Final outputs</p>	<p>Global opera performance; Inquiry-based arts-infused process; opera libretto; musical score; costumes; scenography; documentation of science learning outcomes in the opera program/official posters; pictures; videos; various media documentation</p>
<p>Aims / Educational objectives:</p>	<p>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, as well as Public Relations are designed by the pupils and realized during the project.</p> <p>The “Ghost Particles” scenario 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 which will set the inquiry process for the opera in motion.</p> <p>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.</p> <p>Pupils will be introduced to the common creative impulses of science and the arts.</p> <p>Specifically, the following aims are present:</p> <ul style="list-style-type: none"> ➤ 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

	<p>both the science and arts educational disciplines).</p> <ul style="list-style-type: none"> ➤ 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
<p>Learning environments(physical and computational media involved)</p>	<p>This depends on how each school/institute will choose to participate. A typical school participation which chooses to perform part of the opera will have these environments:</p> <ol style="list-style-type: none"> 7. 2 classroom spaces (1 may be enough in some cases) 8. Musical instruments 9. Raw material for costumes 10. Stage (optional – WASO may be performed without an official stage) 11. Access to scientific information (teacher/internet/book/research center) 12. Good internet connection
<p>Characteristics of learning environments</p>	<p>The learning environment in GSO is global. This necessarily includes networking with countries beyond the European context. This is done by a monthly meeting online during which the various partners meet to discuss the opera’s progression (note: for the 2016 production, these will commence in March).</p> <p>The process is collaborative, creative and flexible. It includes elements which cannot be foreseen in advance.</p> <p>For the classes which are performing, 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. Time zones must be considered, and sleep-overs may be needed for e.g. Australian pupils.</p>
<p>Description of the additional pedagogical framing of the initiative</p>	<p>GSO relies on and facilitates an empowering, democratic process in that all participants recognize their own inputs in the final, collaborative whole, thus providing a dialogue of respect for other participants' creative ideas, indeed, a wise, humanizing approach to learning from, others' creative ideas. Furthermore, GSO necessarily requires collective idea generation and a solution- finding process which is dialogic in nature.</p>

Description of the main activities

In the framework of the CREAT-IT project (2013-2015), WASO activities were conceptualized as arts-infused Inquiry-Based Science Education (IBSE) activities. This is structured around the five IBSE phases suggested by the Cosmos project (2008):

Phase 1: Question Eliciting Activities/Exhibiting Curiosity

Phase 2: Active Investigation

Phase 3: Creation

Phase 4: Discussion

Phase 5: Reflection

During these phases, music composition, libretto writing, staging, scenography, lighting, etc. were all created as an integral part of the science learning process. This process is detailed in the WASO Guidelines (link below).

An approximate month-for-month plan follows:

Spring:

Month	Activity
March	Creating the libretto/meetings start (monthly)
April	Music composition/virtual visit to CERN
May	Dramatization
June	Finalizing libretto and book

SUMMER and Fall:

July	Summer School in Greece &
August	Conference in Norway
September	Rehearsals, costumes, writing training materials, etc.
October	Final rehearsals
November	Performance, possibly coinciding with the Transatlantic Science Week (Norway/USA) (to be confirmed)

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Methods of learning/ training	Digital platform, Inquiry Based Science (IBSE), Creativity development, dramatization, performance, experimentation, collaborative learning, scientific method, discussion, reflection.
End user (depending on the category: school based, school – research center collaboration, professional development)	Schools, research centers, art programs, universities, general public
Involved actors	<p>It is important to know which CREATIONS countries would like to include “Ghost Particles” as part of their implementation\dissemination activities. These will allow us to work more systematically and professionally in those countries. It is important to keep in mind that in these following CREATIONS countries, there already exist “SkyLight” contacts who will continue in the next productions. This would mean that we have already identified interested schools\universities in those countries who could take part in the implementation of CREATIONS, if that is of interest to the CREATIONS project management. <i>These countries are: France, Malta (CNs partner UoMalta), Norway (CNs partner HSH), Spain, Greece (CNs partner EA), UK, Finland (awaiting confirmation from Finnish National Opera), Sweden (CNs partner Vetenskapens Hus), Serbia, Swizerland (CNs partner art@CMS).</i></p> <p>Due to the global character of GSO, the implementation necessarily includes other projects. These are iSCOPE (Norwegian Research Council), Global Hands on Universe, GTTP, RESEO.</p> <p>In addition, P. Stergiopoulos (EA) is creating a network of Greek schools which will interact more closely within the GSO, and provide an example for closer collaboration. Also, M. Sotiriou (SV) will support the networking of GSO with the LSTT initiative.</p>
Location	Online. Physically, in each country, this can be one of the following: School, university/college, science center/museum, research center, or art festival/event.
Connection with the curriculum	<p>Students will explore the art@CMS website, and virtual visits to CERN. They will learn about modern research concerning the relevant particles (Neutrinos, Photons, Higgs Boson).</p> <p>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</p>

	<p>can be of great inspiration to scenography, costumes and music.</p> <p>The opera's synopsis is specifically designed to follow a similar creative process to the one which scientists followed from 1930 and until the recent Neutrino discoveries/proofs. This is done by structuring the opera's dramaturgy to reflect that scientific process. The opera's synopsis is as follows:</p> <p><i>Joao is a Portuguese boy who is curious about the sky and stars. He receives a book from his father, in which he reads about the concept of matter of various cultures and ages. He is especially excited about the story of Pauli, and the way in which Pauli imagined a particle, leading to an exploration spanning over decades. Joao wants to imagine his own particle, but is rejected, and told that it will take many years, perhaps centuries, before that would be possible. Desperate to realize his dream, he invites his friends around the globe to help him imagine this new particle. Together, they study the Ghost Particles, photons, neutrinos, and Higgs Boson, and finally, they imagine a particle of their own. They seek the help of the CMS experiment in order to describe it, and then send a message to the world, inspired by Pauli's radioactive speech: "Dear Creative Ladies and Gentlemen..."</i></p> <p><i>Note: The idea behind the synopsis is to reflect the decades-long creative process leading up to the neutrino discoveries, in the art-creation process of making the opera. The "new particle" and Joao's quest for it, represents that transfer from the science to the art.</i></p>
<p>Evaluation parameters</p>	<p>In the context of the CREATIONS project, the foremost evaluation perspective should be the scientific inquiry process and learning, and how the transdisciplinary character of the project impacts these. Furthermore, the project should be evaluated as a whole. It is also possible to evaluate art outputs, but this may be beyond the scope of the CREATIONS project.</p> <p>There are researchers from Canada who are planning to implement evaluation of GSO in some countries (e.g. USA and India). These can be made available to CREATIONS if needed.</p>
<p>Additional resources</p>	<p>High-speed internet for performers. Otherwise, it depends on the function each class chooses to take part of in the production. Note: not all countries will perform. Some will create music, some will do PR, etc.</p>
<p>Users'/Developers' Required competences</p>	<p>It is logistically challenging to control everything that is happening in this GSO network due to many partners' volunteer work, and the geographical distance, as well as time zones. The GSO is therefore relatively "open" with regard to each alpha-contact's qualifications. The most important is that all the highly qualified persons (artists, scientists, educators, etc.) are within the network itself. Thereafter, in each country there should be people who can guide the activities which that school chose to implement.</p>
<p>Bibliography on a)</p>	<p>Garioian, C. R. & Mathews, J. D. (1996). A common impulse in art and</p>

effective learning environments and b) initiatives	<p>science. Leonardo 29(3), 193-196</p> <p>Craft, A. (2011). Creativity and Education Futures. Changing Childhood and Youth in a Digital Age.</p> <p>Ben-Horin, O. (2014). The WASO Guidelines. EC: CREAT-IT project. Available at: http://www.opendiscoveryspace.eu/edu-object/write-science-opera-waso-guidelines-820499</p> <p>Ben-Horin, O. and Stergiopoulos, P. (2015). "SkyLight – a Global Science Opera Implementation Scenario". Available at: http://www.opendiscoveryspace.eu/edu-object/skylight-global-science-opera-waso-implementation-scenario-833946</p> <p>TV Report, Brazil: http://g1.globo.com/rj/norte-fluminense/rjintertv-2edicao/videos/t/edicoes/v/alunos-de-campos-rj-representam-o-brasil-em-evento-que-reune-opera-e-ciencia-na-web/4513893/</p> <p>Online article: http://galileoteachers.org/skylight-a-global-science-opera/</p>
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5. HSH's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	Write a Science Opera (WASO)
Summary	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.
Settings (a) school based, b) school – research center collaboration, c) professional development)	<p>The WASO project may be realized as:</p> <ul style="list-style-type: none"> a) School-based projects (here it is recommended to have 2-3 weeks with the participating class, but shorter versions ("tasters") of 2 days are also possible) b) School-research center (the scientific content of a WASO project may come from a science teacher, a researcher, a research center, or a science museum/exhibition). c) WASO has been realized as professional development courses (e.g. in the CREAT-IT project), aiming at providing educators with the tools to lead a WASO project in their schools on their own.
Final outputs	Inquiry-based arts-infused process; opera libretto; musical score; costumes; scenography; documentation of science learning outcomes in



	the opera programme/official posters; opera performance
Aims / Educational objectives:	<p>WASO 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. In a WASO project, a scientific theme which is the learning focus in that particular setting is chosen to inspire a creative process in a school, culminating in an operatic performance by the pupils. The complete process is guided by teachers from within a variety of disciplines including both science and the arts. Characters, libretto, composition, stage design, costume, as well as Public Relations and budget are designed by the pupils and realized during the project. Specifically, the following aims are present:</p> <ul style="list-style-type: none"> ➤ 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
Learning environments(physical and computational media involved)	<p>13. 2 classroom spaces (1 may be enough in some cases) 14. Musical instruments 15. Raw material for costumes 16. Stage (optional – WASO may be performed without an official stage) 17. Audio equipment for performance (optional – WASO can be performed “unplugged”) 18. Access to scientific information (teacher/internet/book/research center)</p>
Characteristics of learning environments	<p>The learning environment in WASO 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.</p>

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<p>Description of the additional pedagogical framing of the initiative</p>	<p>WASO relies on and facilitates an empowering, democratic process in that all participants recognize their own inputs in the final, collaborative whole, thus providing a dialogue of respect for other participants' creative ideas, indeed, a wise, humanizing approach to learning from, others' creative ideas. Furthermore, WASO necessarily requires collective idea generation and a solution- finding process which is dialogic in nature.</p>
<p>Description of the main activities</p>	<p>In the framework of the CREAT-IT project (2013-2015), WASO activities were conceptualized as arts-infused Inquiry-Based Science Education (IBSE) activities. This is structured around the five IBSE phases suggested by the Cosmos project (2008):</p> <p>Phase 1: Question Eliciting Activities/Exhibiting Curiosity Phase 2: Active Investigation Phase 3: Creation Phase 4: Discussion Phase 5: Reflection</p> <p>During these phases, music composition, libretto writing, staging, scenography, lighting, etc. were all created as an integral part of the science learning process. This process is detailed in the WASO Guidelines (link below).</p>
<p>Methods of learning/training</p>	<p>Inquiry Based Science (IBSE), Creativity development, dramatization, performance, experimentation, collaborative learning, scientific method, discussion, reflection.</p>
<p>End user (depending on the category: school based, school – research center collaboration, professional development)</p>	<p>This could be a school or a group of teachers at a professional development training course.</p>
<p>Involved actors</p>	<p>School (if realized with children), science educator/Scientist, artists/art educators.</p> <p><i>In the case of school:</i> Recommended to involve the head teacher</p> <p><i>I the case of Professional development:</i> A group of teachers is also involved.</p> <p><i>Media:</i> The media have often been invited to WASO projects, especially in Norway, and have enabled good dissemination of the results of projects. Example: http://www.utdanningsnytt.no/magasin/2015/tredjeklassinger-skaper-opera-ut-av-naturfag/</p>
<p>Location</p>	<p>Can be one of the following: School, university/college, science center/museum, research center, or art festival/event. Also, it is possible to include virtual visits to CERN in the WASO projects.</p>
<p>Connection with the</p>	<p>WASO lends itself to every curriculum topic. Once the curriculum topic has</p>

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curriculum	<p>been chosen, it is highly recommended to consider ways in which that specific topic may be reflected through the various art forms, and thus allow participants to experience that topic in multiple ways. <i>Examples: How would the shape of a wave be represented dramaturgically? How can the structure of a double Helix be represented by musical harmonies? What kind of costumes could a character representing a water molecule wear?</i></p>
Evaluation parameters	<p>In the context of the CREATIONS project, the foremost evaluation perspective should be the scientific inquiry process and learning, and how the transdisciplinary character of the project impacts these. Furthermore, the project should be evaluated as a whole. It is also possible to evaluate art outputs, but this may be beyond the scope of the CREATIONS project.</p> <p>Evaluations will differ for short school workshops (2-3 days), longer school workshops (a week or more), or for CPD workshops.</p> <p>The previous CREAT-IT project (2013-2015) may provide evaluation structures for these various settings if needed.</p> <p>It is recommended for CPD workshop to last 2 days, so as to allow an in-depth experience and time for evaluation, although successful workshops have been realized in 4-5 hours' time.</p>
Additional resources	<p>Musical instruments, raw material for costumes, sound equipment, projector, computers with Word processor and internet, video camera (optional).</p> <p>Note: The success of a WASO project does not depend on expensive equipment. Rather, the approach is to "make do" with the available material so as to be relevant and adaptable for any school, regardless of economic capacity.</p>
Users' /Developers' Required competences	<p>It is crucial that there are enough trainers who know the method, during training workshops. The WASO Guidelines describes the democratic, creative process through which the science operas are produced. It is also crucial to have at least one qualified science educator, at least during part of the project, but preferably for the whole duration.</p> <p>For a week-long summer school, for example, we would need these educators: science, visual arts, music/composition, drama.</p> <p>For a 2-day workshop, we typically have 2 instructors from the arts, and a collaborator (science teacher) available in the school.</p> <p>Note: The WASO method is not about professionals creating an opera for pupils. It is about professionals guiding the pupils' own creations. That said, there will be times during each project when the professionals will have to make tough decisions to ensure that the process is moving forward, especially in the case of a project which concludes with a performance.</p>
Bibliography on a)	<p>Garoian, C. R. & Mathews, J. D. (1996). A common impulse in art and</p>



<p>effective learning environments and initiatives</p>	<p>science. Leonardo 29(3), 193-196</p> <p>Craft, A. (2011). Creativity and Education Futures. Changing Childhood and Youth in a Digital Age.</p> <p>Ben-Horin, O. (2014). The WASO Guidelines. EC: CREAT-IT project. Available at: http://www.opendiscoveryspace.eu/edu-object/write-science-opera-waso-guidelines-820499</p>
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6. UBT's contribution

Initiatives' structure and Effective learning environments	
<p>Title of the Initiative</p>	<p>Bionics – out-of-school learning in the zoo</p>
<p>Summary</p>	<p>In cooperation with the "BIONICUM" at the zoo in Nuremberg a curriculum compliant learning circle about Bionics was established (6th grade).</p> <p>The intervention provides selected bases around the theme of bionics and their diversity.</p> <p>Students gain an overview about different bionic areas and learn the bionics concept and its importance to know.</p>
<p>Settings (a) school based, b) school – research center collaboration, c) professional development)</p>	<p>a) and b)</p>
<p>Final outputs</p>	
<p>Aims / Educational objectives:</p>	<ul style="list-style-type: none"> • 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

	<p>increase of knowledge with the motivation for technology?</p> <ul style="list-style-type: none"> • 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 a influence of certain personality traits?
Learning environments(physical and computational media involved)	<p>In cooperation with the "BIONICUM" at the zoo in Nuremberg a curriculum compliant learning circle about Bionics was established (6th grade).</p> <p>The intervention provides selected bases around the theme of bionics and their diversity.</p> <p>Students gain an overview about different bionic areas and learn the bionics concept and its importance to know.</p>
Characteristics of learning environments	<p><u>Learning circle</u></p> <ul style="list-style-type: none"> • „Hands-on“ stations • Topic: Bionics in the water • Different aspects of bionics directly on the compound <p>Integration of the new exhibition "IdeenreichNatur"</p>
Description of the additional pedagogical framing of the initiative	<ul style="list-style-type: none"> • Cognitive knowledge test • Technology Questionnaire (Rennie & Harding, 1992) • Science Motivation Questionnaire II (Glynn, Taasobshirazi&Brickman, 2009) • Cognitive Load (Sweller, Van Merriënboer&Paas, 1998) • Intrinsic Motivation Inventory (Deci et al., 1981)
Description of the main activities	<p>School Zoo Intervention in the zoo</p> <ol style="list-style-type: none"> 1. Bionics: invention of nature 2. 2a. Faster as current 2b. Dolphin show 2c. Addition: Miracle of the dolphin snout 3. 3a. Fin is not fin 3b. Fin Ray- effect 4. Communication under water 5. Skinthing 6. Addition: harassment human <p>Study design Research target Post-test Directly after intervention Retention-test 1 6 weeks after intervention Retention-test 2</p>

	<p>12 weeks after intervention Pre-test 2 weeks before intervention Retention-test 3 1 year after intervention</p>
Methods of learning/ training	Research-based learning (Inquiry Based Science Education) plays a major role in science education (Bogner&Sotiriou, 2011).
End user (depending on the category: school based, school – research center collaboration, professional development)	school – research center collaboration
Involved actors	
Location	Zoo
Connection with the curriculum	
Evaluation parameters	
Additional resources	
Users’/Developers’ Required competences	<ul style="list-style-type: none"> ✓ related to the nature of science including inquiry knowledge and skills ✓ in framing a discipline in a multidisciplinary scenario ✓ in knowledge of contemporary science ✓ in mastering and implementing a variety of instructional strategies ✓ in sustaining autonomous life-long learning ✓ related to self-reflection and meta-cognition ✓ related to the area of teaching/learning processes within the domain ✓ in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students ✓ addressing students’ common sense knowledge and learning difficulties ✓ in the use of ICTs ✓ in the knowledge, planning and use of curricular materials
Bibliography on a) effective learning environments and b) initiatives	<ul style="list-style-type: none"> • Bogner F.X., Sotiriou S. (2011): A Special Section on Technology-Enhanced Science Education, ASL (Advanced Science Letters), 4(11/12), 3301-3303. • Deci E.L., Schwartz A. J., Sheinman L., Ryan R.M. (1981): An instrument to assess adults' orientations toward control versus autonomy with children: Reflections on intrinsic motivation and perceived competence,

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- Bilder: Mile Cindric

7. NKUA's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	<u>Learning Science Through Theater</u>
Summary	<p>This CREATIONS initiative is designed as a transversal meeting point between preparing and staging a play and an Inquiry-Based Science Education model. It follows a scientific approach while opening doors to experiencing new possibilities on several levels. As part of the exploration towards the play's creation, students are asked to dramatize scientific concepts and knowledge from the curriculum of their courses. The initiative is based on the pedagogical framework developed by the European Project CREAT-IT and the principles of Inquiry Based Science Education (IBSE). Students are also provided with open access to research centers in order to use up-to-date information of science.</p> <p>The play's characters, costumes, music and dance, all represent potential ways of interpreting the students' inquiries. They thus engage in Possibility</p>



	<p>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.</p> <p>This initiative is designed as an approximately 5-month project. Teachers along with students will perform drama, music, dance and video (pupils can use existing videos provided they are licensed to). Each act requires a different number of actors. School groups can choose how many and which acts to stage according to the number of participants and time available. The action can take place as part of the 'project' course of the curriculum or as part of the regular activities of school societies (drama, music etc.). School groups will be expected to spend at least 2 hours per week to prepare and rehearse for the final performance. Teachers of each unique project are free to design the schedule and creative exercises according to their needs and capacities. Furthermore, teachers are supported in both the pedagogical part of the initiative and the directorial-artistic part from scientific collaborators from the University of Athens and directors and actors. The support to teachers and students is provided through visits to schools, online meetings and special workshops.</p>
<p>Settings (a) school based, b) school – research center collaboration, c) professional development)</p>	<ul style="list-style-type: none"> ➤ School Based ➤ School - Research Center Collaboration
<p>Final outputs</p>	<p>Science Theater</p>
<p>Aims / Educational objectives:</p>	<ul style="list-style-type: none"> ➤ 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 <p>More Specifically:</p> <ul style="list-style-type: none"> • Students will learn and build knowledge about scientific concepts from the curriculum of their courses

D2.3 Effective learning environments for inquiry learning and teaching

	<ul style="list-style-type: none"> • 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.
<p>Learning environments(physical and computational media involved)</p>	<ul style="list-style-type: none"> ➤ Classroom ➤ Theater stage ➤ National Center for Scientific Research "Demokritos", ➤ ATLAS or CMS Control Centre
<p>Characteristics of learning environments</p>	<ul style="list-style-type: none"> ➤ Pluralities, possibilities, participation, playfulness (Craft, 2011) ➤ Individual, collaborative and communal activities for change ➤ Risk, immersion and play ➤ Dialogue ➤ Interrelationship of different ways of thinking and knowing ➤ Discipline knowledge ➤ Ethics and trusteeship ➤ Importance of materials ➤ Empowerment and agency ➤ Governance ➤ Public engagement

	<ul style="list-style-type: none"> ➤ Gender equality ➤ Science education ➤ Open access/open science ➤ Ethics ➤ Sustainability ➤ Social justice/inclusion
<p>Description of the additional pedagogical framing of the initiative</p>	<ul style="list-style-type: none"> ➤ Constructionism: Constructionist learning involves students drawing their own conclusions through creative experimentation and the making of social objects ➤ Inquiry Based Learning: reflects the constructivist model of learning, often referred to as active learning ➤ 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 (Smyrniou, et al., 2015). ➤ Meaning Generation Pupils directly connect their movement, gesture and communication with scientific concepts which they perceive, as embedded in the educational activities (Kynigos, Smyrniou&Roussou, 2010). ➤ 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 (Smyrniou&Kynigos, 2012). According to Hutto et al. (2015), embodied learning enhanced the understanding and acquisition of

	<p>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.</p>
<p>Description of the main activities</p>	<p>The CREATIONS initiative activities are conceptualized as Inquiry-Based Science Education (IBSE) activities. This is structured around the five IBSE phases suggested by the Cosmos project (2008):</p> <p>Phase 1: Question Eliciting Activities/Exhibiting Curiosity Optional: Preparatory drama, visual arts and music workshops/classes)</p> <p>Phase 2: Active Investigation</p> <p><i>A. Collaboration with Research Centers</i></p> <p><u>Educational visit to the National Center for Scientific Research "Demokritos"</u>, which can act as mediator, organising information across scientific disciplines and providing tools for understanding complex scientific research, making science understandable and interesting to the young students. More specifically, students will discuss with the research center's researchers about scientific concepts and ideas and they will have their first visit in the research center's scientific labs, where scientific experiments take place.</p> <p>The <u>eMasterclasses Virtual Collaboration</u> activities include a presentation of the rationale of the CERN experiments, a virtual visit to the ATLAS or CMS Control Centre (real time connection with CERN), a discussion with the researchers on shift, and the "hunt for Higgs" challenge by using real data from the detectors that is analyzed with the use of HYPATIA analysis tool that offers access to real data from ATLAS detector at CERN.</p> <p><i>B. Investigating on the Science Theatre Design and Implementation</i></p> <p><u>Script/directing group</u>: Investigate characters and generate ideas for dialogues/actions.</p> <p><u>Actor group</u>: Investigate characters and work on performance in collaboration with script/directing group.</p> <p><u>Music group</u>: Generate musical ideas which correspond to the script.</p> <p><u>Dance group</u>: After consulting with script/directing, actor and music groups, generate choreography ideas to incorporate in the play.</p>

	<p><u>Set/costumes group</u>: Generate ideas after consulting script group and collect materials.</p> <p><u>Video group</u>: Generate ideas after consulting script group and collect or create video clips.)</p> <p>Phase 3: Creation</p> <p>Rehearsals on all levels (costumes, music, staging, performances, etc.) & final performance of play.</p> <p>Students will be awarded for various categories, such as best overall presentation, best script, best direction, best soundtrack, best scenery, best choreography and best costumes.</p> <p>Phase 4: Discussion</p> <p>Discuss learnings around the scientific topic explored as well as the creative methods used.</p> <p>Phase 5: Reflection</p> <p>Discuss specific issues (stage design, music composition, group dialogue, ethical decision-making regarding inclusion of all students in the creative process, etc.).</p>
Methods of learning/training	Inquiry Based Science Learning (IBSE), dramatization, experimentation, collaborative learning, scientific method, discussion.
End user (depending on the category: school based, school – research center collaboration, professional development)	Students
Involved actors	<ul style="list-style-type: none"> ➤ Teachers ➤ Students ➤ Researchers ➤ National Center for Scientific Research “Demokritos” ➤ CERN ➤ scientific collaborators from the University of Athens ➤ Directors and actors
Location	<ul style="list-style-type: none"> ➤ School Classroom and/or School Music room ➤ Research Centers (such as National Center for Scientific Research “Demokritos”) ➤ Place of final event (Athens, Thessaloniki and Heraklion, Greece)
Connection with the	The theme of the script outlines will be chosen by the students along with

D2.3 Effective learning environments for inquiry learning and teaching

curriculum	their teachers. This topic refers to scientific concepts and knowledge from the curriculum of their courses which are included in the Greek National Curriculum from the 1st year to the 5th year of High School (ages 12-16), without excluding older pupils.
Evaluation parameters	<ul style="list-style-type: none"> ➤ 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. ➤ 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 also some significant moves (embodied movements) that they used for the representation of scientific knowledge. ➤ Teachers are expected to fill an observation rubric, which is significantly important about the scientific and pedagogical evaluation of the whole procedure.
Additional resources	<ul style="list-style-type: none"> ➤ Musical instruments, materials for making sets and costumes. <i>Optional:</i> Stage lights and sound equipment. ➤ Computer with Word processor (for script writing), internet (to search for information and online connection with CERN), camera (to record the performance). <i>Optional:</i> video editing software (for video production)
Users' / Developers' Required competences	<ul style="list-style-type: none"> ➤ Some basic knowledge of Biology, Physics, Geology and Astronomy. The implementation of this scenario is very flexible, since the teachers and the students will choose the topic they want to focus on, depending on their interests and depth of knowledge. Pupils can also use their collaboration with the Research Centers in order to understand basic concepts or explore specific topics of interest in greater depth. <p><i>Optional:</i> music lessons including composition exercises; basic drama exercises; dance; arts & crafts classes; experience with school stage performances is an advantage</p>
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8. NKUA's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	Student Parliament (SP)
<p>Summary</p>	<p>The SP CREATIONS Initiative'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".</p> <p>The SP's main topic for negotiations is 'The future of the human being' further categorized in seven sub-topics: 1) The Human Brain, 2) Living and eating healthy – but how?, 3) The changing reproduction of mankind, 4) Stem cells – the potential allrounders?, 5) Exploring the inside, 6) Augmented human: optimising the human and 7) Imitating nature.</p> <p>In the project there are currently participating 56 schools both public and private. 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.</p> <p>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. Students are free to present evidence or realization of their claims through creative, alternative and innovative approaches.</p>

<p>Settings (a) school based, b) school – research center collaboration, c) professional development</p>	<p>(a) school based, b) school – research center collaboration, c) professional development (with the implementation of workshops)</p>
<p>Final outputs</p>	<p>Science Debate</p>
<p>Aims / Educational objectives:</p>	<p>The aim of the project 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 that 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.</p> <p>Main aims of the project is students’:</p> <ul style="list-style-type: none"> ➤ 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) ➤ Developing spirit of cooperation and teamwork <p>Main objectives of the project was students to:</p> <ul style="list-style-type: none"> • 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

	<ul style="list-style-type: none"> • develop attitudes befitting a scientific ethos • Link with science and society in a personal context
Learning environments(physical and computational media involved)	<p>Formal and Informal learning settings</p> <ul style="list-style-type: none"> ➤ Classroom ➤ Venue for final debate event ➤ Research center (physical visit or virtual) ➤ Open Discovery Space
Characteristics of learning environments	<ul style="list-style-type: none"> ✓ Governance ✓ Public engagement ✓ Gender equality ✓ Science education ✓ Open access ✓ Ethics ✓ Sustainability ✓ Social justice ✓ Observe Classroom Dynamics ✓ Personalize Large Classes ✓ Shift from a Competitive to a Cooperative Educational Model ✓ Consider a Variety of Examination Options ✓ Foster Self-Confidence
Description of the additional pedagogical framing of the initiative	<ul style="list-style-type: none"> ✓ Inquiry Based Learning reflects the constructivist model of learning, often referred to as active learning ✓ Argumentation approach: Byengaging 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 (Smyrniou, et al., 2015). ✓ Challenge-based learning accommodates the conditions for engaging students in authentic issues and providing the adequate context for students themselves to do science rather than simply act under the demands of a science curriculum (Johnson, et al, 2009)

	<ul style="list-style-type: none"> ✓ Collaborative learning in the form of argumentative discourse produced in collaborative problem-solving situations is an empowering interactive learning mechanism in which students engage cognitively in potential conceptual transformations and 'constructive interactions' (Baker, 1999). ✓ Contextual Scenario-Based Design intentionally lack detail- their aim is, in part, to seed a discussion between the actors and the designers that 'discovers' the detail. They are also rich in context and global purpose (Howard, et al., 2002).
<p>Description of the main activities</p>	<p>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.</p> <p>Phase 1: Question Eliciting Activities/Exhibiting Curiosity</p> <ul style="list-style-type: none"> ➤ Building interest in scientific issues and their explanations/social impact. ➤ Relevance of the content to the daily lives of students: All of the open-ended inquiries are related to students' lives. This highlights to students the science that can be found in daily life ➤ Define questions from current knowledge ➤ Understanding science as a process not as stable facts. Understanding science as an on-going, not consolidated process. <p>The teacher tries to attract the students' attention by eliciting students' relevant questions or pinpoint unexplored areas to the topic under negotiation.</p> <p>Students are engaged by scientifically oriented questions and observations.</p> <p>Phase 2: Active Investigation: Building up informed citizens: Students understanding the nature of Science & Science in society</p> <ul style="list-style-type: none"> ➤ Propose preliminary explanations or hypotheses <p>Students propose some possible explanations to the questions that emerged from the previous activity. The teacher identifies possible</p>

misconceptions.

- **Plan and conduct simple investigation**
- **Doing science: experimenting, analysing, interpreting, redefining explanations:**

The activities start with an open scientific question; experiments are conducted to explore different answers following observation, data collection and interpretation, development of prediction and discussion of scientific ideas. The scientific method is the basis of all the work done.

Students give priority to evidence, which allows them to develop explanations that address scientifically oriented questions. The teacher facilitates the process.

- **Collaboration with Research Centers**

Educational visit to scientific research centers. Students will discuss with the research center's researchers about scientific concepts and ideas. Discuss on the strengths and weaknesses of their investigation as well as further approaches of the issue under negotiation. Collaboration with experts is also realized through the Open Discovery Space.

Phase 3: Creation

- **Gather evidence from observation**

Teacher divides students in groups. Each group of students formulates and evaluates explanations from evidence to address scientifically oriented questions.

- **Apply/Investigate alternative solutions to address the scientific issue.**

Students engage in analysing data (organizing data, finding patterns, assessing data quality), interpreting data, making inferences, modeling, etc.).

Phase 4: Discussion

- **Explanation based on evidence**

Discuss learning around the scientific topic explored

- **Consider other explanations**

Each group of students evaluates its explanations in light of alternative explanations, particularly those reflecting scientific understanding.

Phase 5: Reflection

	<p>➤ Communicate explanation</p> <p>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. 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 alternatively models for their illustration.</p> <p>Final activity: The Debate event</p> <p>In the simulated parliament, 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. Students use the argumentation approach to back up their claims by developing warrants and refute their peers' contradictory arguments.</p>
Methods of learning/training	Inquiry Based Science Learning (IBSE), experimentation, collaborative learning, scientific method, argumentation, modeling.
End user (depending on the category: school based, school – research center collaboration, professional development)	Both students and teachers
Involved actors	Scientific centers scientists/researchers
Location	School Classroom Research Centers (physical or virtual visit)
Connection with the curriculum	Various and interdisciplinary based on the scientific issue under negotiation
Evaluation parameters	<ul style="list-style-type: none"> • External evaluator: The Student Parliament Scientific Committee • Tools used: questionnaires, observation, interviews, experts' and teachers' report
Additional resources	http://www.scienceview.gr/projects/ http://studentparliament.weebly.com/thetaepsilonpsilonmualphatauiotakappa941

	<p>sigmaf-epsilon972tauetauepsilonpsilonsigma.html</p> <p>http://www.opendiscoveryspace.eu/community/greek-student-parliament-science-834221</p>
<p>Users'/Developers' Required competences</p>	<ul style="list-style-type: none"> ✓ related to the nature of science including inquiry knowledge and skills ✓ in framing a discipline in a multidisciplinary scenario ✓ in knowledge of contemporary science ✓ in mastering and implementing a variety of instructional strategies ✓ in sustaining autonomous life-long learning ✓ related to self-reflection and meta-cognition ✓ related to the area of teaching/learning processes within the domain ✓ in using laboratories, experiments, projects, modeling and outdoor activities to build understanding and skills of students ✓ addressing students' common sense knowledge and learning difficulties ✓ in the use of ICTs ✓ in the knowledge, planning and use of curricular materials
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9. NKUA's contribution

Initiatives' framework – Creating an Engaging Classroom	
Title of the Initiative	<u>Introducing the Ghost particles</u>
Summary	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



	<p>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 physics research – “The Ghost Particles, neutrinos”. <i>Nobel prize winning in physics for 2015.</i></p> <p>School curriculum in most countries includes very little regarding particle physics.</p> <p>The main goal of the specific initiative is to incorporate a series of activities which will allow us to create an engaging learning environment in classroom.</p> <p>As presented below the scenario template includes Interactive computer simulations, logo based or based on Flash or Unity, half-baked microworlds (Kynigos, 2012), videos and virtual visits (Cern and Wipac), games, role playing, and creative artistic mediation (drawings, posters, comics and short theatrical plays, etc.).</p> <p>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.</p>
<p>Settings (a) school based, (b) school – researchers, (c) professional development)</p>	<ul style="list-style-type: none"> ➤ School Based ➤ School – research center virtual collaboration ➤ Exploitation of the initiative as an exemplary case study for professional development
<p>Final outputs</p>	<ul style="list-style-type: none"> ➤ Students deliverables – Scientific artwork (students’ design of decay simulations in software, drawings of elementary particles/neutrinos, short theatrical performance/ role playing assuming the underlying principles of neutrinos)
<p>Aims / Educational objectives:</p>	<ul style="list-style-type: none"> ➤ Inquiry of scientific concepts ➤ Competences of critical / analytical thinking ➤ Experience 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

	<ul style="list-style-type: none"> ➤ Combination of Science and Art <p>More Specifically:</p> <ul style="list-style-type: none"> • Students will have the opportunity to approach basic principles and concepts of the subatomic world "<i>The Standard Model Of Particle Physics</i>". • 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.
Learning environments	<ul style="list-style-type: none"> ➤ Classroom ➤ PC labs (computer models and simulations) ➤ Virtual labs (Cern) ➤ WIPAC (video demonstrator)
Characteristics of learning environments	<ul style="list-style-type: none"> ➤ Inquiry-based Science education ➤ Personal engagement and hands-on experimentation through interactive simulating environments (computer simulations, logo based or based on Flash or Unity) ➤ Combination of art and Science
Description of the additional pedagogical framing of the initiative	<ul style="list-style-type: none"> ➤ <i>Inquiry Based Learning (IBSE)</i>: Educational framework that aspires to engage students in an authentic scientific discovery process. ➤ <i>Modeling</i>: Utilization and construction of computer based models that contribute to the explanation and assimilation of demanding scientific concepts. ➤ <i>Science culture and creativity</i>: Researchers, interdependence among scientific findings and historical and cultural framework that lead to breakthrough scientific discoveries. <i>'...to learn science is not to learn what the last generation of scientists thought the world was like: it is</i>

to learn how each new generation of scientists re-makes our view of the world. Ultimately, it is to learn how to have some degree of participation in this process of invention and discovery', (Lemke, 2009)

- *Content and Language Integrated Learning (CLIL):* application of 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)

Description of the main activities

The 'Introducing the Ghost particles' initiative consists of a series of activities that are designed in such a way, that student's high engagement and personal involvement can be accomplished through inquiry and negotiation of demanding scientific concepts and procedures regarding the field of particle physics.

Brainstorming and Inquiry phase

Students 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.

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.

	<p><u>Students' simulation-based design phase</u></p> <p>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.</p> <p><u>Virtual visits phase</u></p> <p>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.</p> <p><u>Students' artistic implementation of scientific concepts</u></p> <p>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.).</p>
Methods of learning	Inquiry Based Science Learning (IBSE) , Modeling, Creativity, Argumentation, Drawing, Performance
End user (depending on the category: school based, school – research center collaboration, professional development)	Students of ages 12-18 (secondary schools)
Involved actors	<ul style="list-style-type: none"> ➤ Teachers ➤ Students ➤ Researchers ➤ Research infrastructures
Location	<ul style="list-style-type: none"> ➤ School Classroom ➤ Computer labs ➤ Virtual Visits to CERN infrastructures.
Connection with the curriculum	<ul style="list-style-type: none"> ➤ All activities are designed as extensions to the current school curriculum, and can be applied in multiple ways in multiple science education subjects (such as an independent school project in physics, chemistry, etc.)

Evaluation parameters	<ul style="list-style-type: none"> ➤ Students can compare their initial ideas with the concepts attained through the above process. ➤ Students' deliverables
Additional resources	<p>http://atlas-live-virtual-visit.web.cern.ch/atlas-live-virtual-visit/ https://www.youtube.com/watch?v=VOKjXsGRvoA https://wipac.wisc.edu/ghostparticle http://etl.ppp.uoa.gr/content/download/index_download_en.htm http://hypatia.phys.uoa.gr/ http://www.nobelprize.org/nobel_prizes/physics/laureates/2015/popular-physicsprize2015.pdf http://www.nobelprize.org/nobel_prizes/physics/laureates/2015/advanced-physicsprize2015.pdf</p>
Required competences	<ul style="list-style-type: none"> ➤ Basic computer competences (additional information or glossary will be provided if necessary) ➤ Basic knowledge concerning chemical elements (periodic table) and elemental particles (molecules & atoms)
Bibliography	<ul style="list-style-type: none"> ➤ Pedaste, M. et al (2015): Phases of inquiry based learning: Definitions and the inquiry cycle. Educational research review. DOI 10.1016/j.edurev.205.02.003 ➤ Kynigos, C. (2002a). Mind Tools and Informational Media, Pedagogical Uses of New Technologies for the Development of Educational Practice, Athens: Kastaniotis Pubs. ➤ Smyrnaïou, Z., Moustaki, F., Kynigos, C., (2012): <i>Student's constructionst game modeling activities as part of inquiry learning processes</i>. Electronic Journal of e-learning vol 10 issue 2. ➤ Smyrnaïou, Z., & Weil-Barais, A. (2004). Cognitive evaluation of a technology based learning environment for scientific education. In <i>Computer Based Learning in Sciences, Proceedings of Sixth International Conference, CBLIS</i> (pp. 5–10). ➤ Orfanos, S., & Dimitracopoulou, A. (2003). Technology Based Modelling Activities and the Contribution to Learning Concepts' Relations in Physics. In <i>Proceedings of II International Conference on multimedia ICT's in Education</i> (pp. 1353–1357).

10. CERN's contribution

Initiatives' structure and Effective learning environments

Title of the Initiative	Science&Art@School
<p>Summary</p>	<p>Science&Art@School promotes the idea that particle physicists and artists share fertile common ground in their parallel efforts to understand <i>physis</i> (the Greek word for <i>nature</i>). Creating a bridge between the two disciplines is worthwhile since it can lead to a deeper understanding of each subject area. It also helps young people to think creatively and critically about the collaborative scientific effort being made at CERN, the world's largest particle physics laboratory.</p> <p>Science&Art@School takes the art@CMS concept a step further by bringing second-level students from the arts and science curricula together with CMS scientists, science educators and art educators during extended learning periods with the aim to help students:</p> <ul style="list-style-type: none"> • Understand how scientific research in high energy physics at CMS and CERN works • explore how CMS researchers and artists work and view each other's world • engage in and create artistic works inspired by the big physics questions driving scientific work at CMS and CERN, and • develop positive attitudes towards science and technology related work at large research infrastructures like CMS and CERN.
<p>Settings (a) school based, b) school – research center collaboration, c)</p>	<p>a) b)</p> <p>Note: A museum or art space may also be an appropriate setting for this initiative.</p>



professional development)	
Final outputs	<p>Creative output: original artworks and/or performances developed by students that are inspired by particle physics, CMS and CERN.</p> <p>Exhibitions of these artworks in school, museum, art space, science festival etc.</p> <p>Performances in school, museum, science festival etc.</p>
Aims / Educational objectives:	<ul style="list-style-type: none"> ➤ Active participation in a dialogical process between science and art, creativity and identity, and ideas ➤ Develop understanding of and engagement with both scientific and artistic lines of thinking through hands-on experimentation with real scientific data and development of art objects ➤ Develop spirit of cooperation and teamwork through collaborative practice including play ➤ Develop positive attitudes, and especially trust in the norms, values and rules of scientific as well as artistic practice
Learning environments(physical and computational media involved)	<ul style="list-style-type: none"> ➤ School/classroom ➤ Science center (physically or through virtual visit) ➤ Museum or art space ➤ Science festival
Characteristics of learning environments	<ul style="list-style-type: none"> ➤ Interdisciplinarity ➤ Dialogue ➤ Collaborative and communal activities ➤ Balance and navigation ➤ Empowerment and agency ➤ Risk, immersion and play ➤ Possibilities ➤ Ethics and trusteeship ➤ Open and responsible science ➤ Public engagement and communication

	<ul style="list-style-type: none"> ➤ Social inclusion and impact
Description of the additional pedagogical framing of the initiative	<ul style="list-style-type: none"> ➤ Inquiry-based learning through Particle Physics Masterclass exercise ➤ Creativity-based learning through development of art objects or performances
Description of the main activities	<p>A typical Science&Art@School workshop lasts three days and includes the following activities:</p> <ul style="list-style-type: none"> ➤ Particle physics Masterclass (Day 1) <ul style="list-style-type: none"> ○ Lecture by a scientist on particle physics, CERN and CMS ○ Virtual visit to CERN/CMS ○ Hands-on experimentation with scientific data (via use of virtual lab) from the CMS (or other LHC) experiment ➤ Art workshop (Day 2) <ul style="list-style-type: none"> ○ Lecture by a science educator on the interconnections between science and the arts ○ Brainstorming session aimed at developing ideas and art prototypes ○ Development of art objects ➤ Presentation (Day 3) <ul style="list-style-type: none"> ○ Exhibition of art objects in school or museum
Methods of learning/ training	<p>IBSE especially in relation to the Particle Physics Masterclass part of the workshop</p> <p>Collaborative learning, game-based learning, creativity-based learning especially in relation to the art development part of the workshop</p>
End user (depending on the category: school based, school – research center collaboration, professional development)	<p>Students (12-18y) depending on the level of complexity required in the particle physics masterclass</p>
Involved actors	<ul style="list-style-type: none"> ➤ Students (12-18y)

	<ul style="list-style-type: none"> ➤ Science teachers ➤ Art teachers ➤ Scientists/Researchers ➤ Science education specialists ➤ Artists, performers, designers ➤ Museum or art space curators ➤ General public
Location	<ul style="list-style-type: none"> ➤ School ➤ Research center (physically or virtually) ➤ Museum or art space ➤ Science festival (or equivalent)
Connection with the curriculum	<p>The workshop, at least its Masterclass part, fits in or complements the standard science curriculum of many European countries. In addition, a very good fit can be found in the case of the "Projects" that are part of many curricula across Europe.</p>
Evaluation parameters	<p>Science&Art@School incorporates evaluation parameters in:</p> <p>a) Virtual Visit part. Teachers are invited to assess the virtual visit by completing an online questionnaire. They are also invited to gather students' qualitative feedback and include this in a report.</p> <p>b) Masterclass part. Students are invited to compare their results of their analysis to the official results published by the CMS experiment or with the results obtained by other teams working on the same analysis</p> <p>c) Art part. Students' artworks are evaluated by the art@CMS team based on their originality, creativity and communicability of scientific concepts to general public. Selected artworks are then included in the art@CMS travelling exhibition.</p>
Additional resources	<p>http://artcms.web.cern.ch/artcms/</p> <p>http://scienceartschool.blogspot.ch/2014/04/science-workshop-2014-graz.html</p> <p>http://scienceartschool.blogspot.ch/2013/06/english-version.html</p>

	https://www.youtube.com/watch?v=yTqDm0Yp04E
Users' / Developers' Required competences	<ul style="list-style-type: none"> ➤ Basic knowledge of ICTs ➤ Basic understanding of physics
Bibliography on effective learning environments	<p>a) Conference presentations: EPS High Energy Physics 2015 Conference, Vienna, 22-29 July</p> <p>b) Conferencepapers: Alexopoulos, A. et al. (2015) Resources for Education and Outreach Activities: Discussion Session. The European Physical Society Conference on High Energy Physics, Vienna, 22-29 July.[available at http://cds.cern.ch/record/2132291/files/ATL-OREACH-PROC-2016-002.pdf]</p> <p>Hoch, M. &Alexopoulos, A. (2014) ART@CMS and SCIENCE&ART@SCHOOL: Novel Education and Communication Channels for Particle Physics. Proceedings of the the 14th ICATPP Conference, Vol. 1, 728-736. [available at http://adsabs.harvard.edu/abs/2014apsp.conf..728H]</p>

