

D3.1.x Science&Art@School

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1 Introduction / Demonstrator Identity

1.1 Subject Domain

Particle Physics, Physics

1.2 Type of Activity

This activity is a combination of:

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

1.3 Duration

This is typically a three-day activity

1.4 Setting (formal / informal learning)

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

1.5 Effective Learning Environment

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

2 Rationale of the Activity / Educational Approach

2.1 Challenge

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

2.2 Added Value

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

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

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

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

3 Learning Objectives

3.1 Domain specific objectives

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

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

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

3.2 General skills objectives

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

In line with the P21[®] Framework for 21st Century Learning¹, *Science&Art@School* aims to equip students with the following *Learning and Innovation Skills*:

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

The above skills are described in more detail in the P21[®] Framework Definitions document².

¹<http://www.p21.org/about-us/p21-framework>

²http://www.p21.org/storage/documents/docs/P21_Framework_Definitions_New_Logo_2015.pdf



4 Demonstrator characteristics and Needs of Students

4.1 Aim of the demonstrator

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

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

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

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

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

4.2 Student needs addressed

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

³<http://www.allminds.ch> & <http://www.designcouncil.org.uk>

5 Learning Activities & Effective Learning Environments





D3.1 CREATIONS Demonstrators

<p>Science topic: Particle Physics, Physics</p> <p>Relevance to national curriculum: No direct relevance to Swiss curriculum but strong connection to the International Baccalaureate® (IB) Programme as well as to other national curricula</p> <p>Class information</p> <p>Year Group: Junior high school; Senior high school Age range: 12-17 Sex: Both</p> <p>Pupil Ability: Mixed (The scenario allows space for pupils of various abilities to participate)</p>	<p>Materials and Resources</p> <p><i>What do you need? (eg. printed questionnaires, teleconference, etc.)</i></p> <ul style="list-style-type: none"> - Computers, Internet (for the CMS masterclass part) - Videoconferencing equipment (for the CMS virtual visit part) - Art materials and props (for the production of artworks part) <p><i>Where will the learning take place? On site or off site? In several spaces? (e.g. science laboratory, drama space etc), or one?</i></p> <ul style="list-style-type: none"> - CMS masterclass can take place in school or CMS institute - CMS virtual visit part can take place in school - Production of artworks part can take place in school or museum or art centre - Exhibition can take place in school or museum or art centre <p>Health and Safety implications? None</p> <p>Technology? Computers with internet access and videoconferencing equipment for the CMS virtual visit part</p> <p>Teacher support? Scaffolding</p>
<p>Prior pupil knowledge</p> <p>While no prior knowledge of particle physics is required, a preparatory session initiated by the science teacher is welcomed. In this session, the science teacher is advised to ignite students' curiosity by showing relevant audiovisual material or inviting students to do so at home. The ultimate aim is to initiate the inquiry cycle by posing a "big question" in particle physics that will then be followed up by the students.</p>	

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

During this scenario, students will:

Day 1

- Be introduced to “big ideas” in particle physics (e.g. The Standard Model)
- Explore fundamental concepts and methods of particle physics research (Particle accelerators and particle detectors)
- Analyse real particle physics data with the use of a virtual lab (CMS mini-masterclass)
- Meet and talk to CMS scientists virtually (CMS virtual visit - optional)
- Be introduced to the interconnections of science and art

Day 2:

- Be introduced to the interconnections of science and art (cont’d)
- Develop concepts and define design framework for artwork production
- Implement and produce artworks using a variety of media

Day 3:

- Communicate the whole process through means of public outreach (e.g. exhibition)

Assessment

- Self-evaluation
 - Peer evaluation
 - Portfolio assessment
- (evaluation template available at Section 7)

Differentiation

How can the activities be adapted to the needs of individual pupils?

Science&Art@School is flexible and interdisciplinary by nature and as such speaks well to a diverse group of students.

Key Concepts and Terminology

Science terminology: energy, momentum, charge, Standard Model, Big Bang, hadrons, Higgs boson, dark matter, antimatter, supersymmetry, Planck scale, string theory

Arts terminology: abstract, acrylic, harmony, futurism, minimalism, mixed media, montage, mosaic, neutral, perspective, pop art, style, symbolism, triptych



Session Objectives:

During this scenario, students will:

- engage with big questions about the past, present and future of the Universe (e.g. “where do we come from? What are we made of? Where are we going?”)
- attempt to answer and reflect upon these questions, and communicate their interpretation through tools for authentic scientific inquiry but also through creative experimentation and artistic expression

Learning activities in terms of CREATIONS Approach

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



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



		conservation of energy, conservation of momentum) Embark on artwork production	Art teacher: Invites students to ignite dialogue on the “beauty of science” (e.g. data visualisation) and its potential connection with artistic projects.	
Phase 4 EXPLAIN: students formulate an explanation based on evidence	Students use evidence they have generated and analysed to consider <i>possibilities</i> for explanations that are original to them. They use argumentation and <i>dialogue</i> to decide on the relative merits of the explanations they formulate, <i>playing</i> with ideas.	Discuss the findings of the masterclass with scientist and teacher. Develop scientific argumentation Explain their own rationale and design framework to art teacher	Science teacher and art teacher act as facilitators	
Phase 5 CONNECT: students connect explanations to scientific knowledge	Students connect their explanations with scientific knowledge, using <i>different ways of thinking and knowing</i> ('knowing that', 'knowing how', and 'knowing why') to relate their ideas to both disciplinary knowledge and to <i>interdisciplinary</i> knowledge to understand the origin of their ideas and reflect on the strength of their evidence and explanations in relation to the original question.	Make connections between scientific and artistic inquiry Compare different methodologies and skills they used for physics masterclass and artwork production	Science teacher and art teacher act as facilitators	



<p>Phase 6</p> <p>COMMUNICATE: students communicate and justify explanation</p>	<p>Communication of <i>possibilities</i>, ideas and justifications through <i>dialogue</i> with other students, with science educators, and with professional scientists offer students the chance to test their new thinking and experience and be <i>immersed</i> in a key part of the scientific process. Such communication is crucial to an <i>ethical</i> approach to working scientifically.</p>	<p><i>Scientific investigation part (Masterclass):</i> Present the results of their analysis to other students, teacher and scientist as part of the CMS masterclass</p> <p><i>Artistic creation part:</i> Present their artworks during the exhibition; they document in a visually appealing manner the development of their artwork from inception to completion. This documentation becomes integral part of the artwork and its communication.</p>	<p>Science teacher and art teacher act as facilitators</p>	<p>Art exhibition</p>
<p>Phase 7</p> <p>REFLECT: students reflect on the inquiry process and their learning</p>	<p><i>Individual, collaborative and community-based</i> reflective <i>activity for change</i> both consolidates learning and enables students and teachers to balance educational tensions such as that between open-ended inquiry learning and the curriculum and assessment requirements of education.</p>	<p>Discuss and reflect upon the evaluation of their work. Explore what worked well and what did not work that well.</p>	<p>Science teacher and art teacher act as facilitators</p>	





D3.1 CREATIONS Demonstrators

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6 Additional Information

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

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

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

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

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

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



7 Assessment

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

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

- self-evaluation
- peer evaluation
- portfolio assessment

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

Evaluation Template for *Science&Art@School* Workshop

Part 1 Discover	
<ul style="list-style-type: none"> Concept Brainstorming Research Analysis 	Notes
Part 2 Define	
<ul style="list-style-type: none"> Concept Scope Limitations Review, refine, reflect 	Notes
Part 3 Engage	
<ul style="list-style-type: none"> Concept Development Final Learning outcomes Failing or missing Mediocre still work to do Job done 	Notes Closing comment

8 Possible Extension

In the framework of the art@CMS programme, *Science&Art@School* workshops have been piloted in several schools across six countries in Europe, US and Africa. Specifically, and based on pilot implementation in the International School of Geneva (ECOLINT) over the last three years, *Science&Art@School* is intended to be built as a unit in programmes such as the Visual Arts International Baccalaureate® (IB) Programme⁴. On February 2016, there were more than 5,000 IB programmes offered worldwide across more than 4,000 schools.

⁴<http://www.ibo.org>



9 References

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