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## Checkpoint Leonardo – combining informal science and art education to primary and science teacher education

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### Abstract

*Both artists and scientists want to make the invisible world visible. Checkpoint Leonardo (CPL) is a project for teaching and learning the art and science ways to gain knowledge of the world in informal museum and school education simultaneously. It consists of a series of art exhibitions with tailored workshops based on the scientific and artistic perspectives of the exhibit artworks. The first four workshops were designed and instructed for the conceptual level of 6th grade pupils by interdisciplinary groups of physics student teachers and elementary school student teachers. These workshops studied different ways of perceiving (related to cubism), infrared imaging, oxidation as a source of color, and acid-base indicators. The basis for all workshops was to use the techniques and represent the results in an aesthetic manner. As the work continues and accumulates, the representations combine into an artistic project as well as a scientific body of results. This project was a volunteer part of pedagogical studies covering courses of pedagogy of arts and science and it was co-instructed by lecturers of pedagogy of science, art and museum pedagogies at the University of Jyväskylä and Jyväskylä Art museum, and the regional artist group Live Herring. Also, a series of lectures in the theme of different ways of perceiving the world was included in the Checkpoint Leonardo project. During the project we acquired and analyzed essays on students' ideas of nature of science and aesthetic and empirical ways of knowing world and their development in this project. Only 41% of the student teachers mentioned the empirical nature of scientific knowledge prior the project and 16% of them claimed that scientific process does not permeate creativity.*

Keywords: Nature of science and art, museum pedagogy, teacher education

### Introduction

Finnish primary schooling is rated as a first class system by the Pisa exam, yet many Finnish children do not enjoy school. An extensive study performed by the Finnish Ministry of Education looked into the subjects of music, visual arts, and crafts [1]. It shows how the learning in these subjects is far from the criteria of the curricula. The saddest part of this study shows how boys, in particular, dislike and have difficulties learning in the art classes. At the same time, the universal problem of girls disliking the science classes is regrettably true also in Finland [2]. On the other hand, children do enjoy both science and art museum visits. Still, we observe daily that many science and elementary school teachers experience art and science museums as unfamiliar and uneasy to approach and apply as a learning environment.

The usability and the aesthetics are important qualifications of the modern products, just as the science and the technology behind them. Early learning to understand different ways to perceive the world, benefits the later education of work force to the thinking of modern cross disciplinary research and development processes. An integrated curriculum could

help making students to bridge a scientific meaning and other meanings, artistic and non-artistic, in their studies [3]. However, there is little – if any – discourse between the arts and sciences, for example, at school.

From these points of view the science and art educators of the University of Jyväskylä approached the Jyväskylä Art Museum to construct an exhibition combining the resources of the three parties. The idea was to combine our elementary school student teachers in the courses of art pedagogy (EAT) and science pedagogy (EST), and physics (single subject) student teachers (SPT) to work together in order to learn to instruct pupils in the two disciplines simultaneously; and in the museum environment. The artworks of the exhibition were suggested first by the members of the Art Museum, taking into account the science integrating nature and the resources of this project. After a short introduction to the exhibition and the idea of combining science and art education, an open task was given to the student teachers: “construct and instruct an intervention to teach something meaningful in science and arts for 6<sup>th</sup> grade students in the museum”. Our town region defines museum pedagogy as a key point in education for that age group in the curricula.

The basic purpose of this Checkpoint Leonardo (CPL) project is to offer a challenging authentic environment for student teachers to develop their skills in multi professional co-operation, diverse learning environments and cross subject themes. The name Checkpoint Leonardo refers not only to contact of science and art in Leonardo da Vinci, but also to node of science, art and mathematics by Leonardo Pisano, known better as Fibonacci whose sequence of numbers may be used to approximate the golden spiral or golden ratio.

### **Theoretical background**

Albert Einstein has said that the common feature of science and art is the spirit of mystery. To go slightly further from the spirit, artists and scientists share a common interest to make visual representations of the world, both visible and invisible. The ancient Greek mathematics, the language of science, was based on geometry, in which the rules were explained and demonstrated by visible forms. An invisible branch of mathematics, algebra, with concepts such as polynomials with high dimensions, negative numbers and zero and infinity, developed in India later in the 8<sup>th</sup> century. The efforts to visualize zero or infinity lead to the vanishing point imagery and development in the renaissance arts [4].

In physics, visible are the phenomena (“which appears”), which are directly observable by our senses. A beam of light travelling through a dust cloud is an example of these. It can be investigated in a concrete way by direct observations. On the other hand, everything cannot be sensed directly. A wave of light is an example of a noumenon (“which is thought”), an event of the invisible physical world. Constructing representations of these requires creativity, higher cognition and use of analogies. In his philosophy [5], Immanuel Kant wanted to separate these two “ways of seeing”. As first coined by Kant, these are frequently referred to by German words “anschaulichkeit” (visualizability) and “anschauung” (visualization) respectively [6]. Kant’s Philosophy was an integral part of German school education in the early 1900s and it has been considered to have a significant role in the construction of modern physics, as many of the pioneering scientists were brought up in that environment. In agreement with this philosophy we want our students to learn to identify the difference between an observation and an inference. We believe that this understanding can be developed in combined education of science and art.

The strict distinction between observation and inference is also one of the key issues in nature of science (NOS). NOS refers to epistemology and sociology of science as a way of knowing but also the values, beliefs inherent to scientific knowledge and its development [7]. To map our student teachers' ideas of knowing the science we used six core ideas defined for 6th grade teachers to understand NOS: scientific knowledge is tentative, empirical, theory-laden, partly the product of human inference, needs imagination, and creativity, and lastly, socially and culturally embedded [8].

### **Description of the Project**

The CPL project was a volunteer part of pedagogy of science and art, integrating separate courses. The courses and their resources are presented in the Table 1.

Table 1. The Physics subject teacher and elementary teacher courses of the University of Jyväskylä having resources for integrated CPL project. See more about the curricula: [9].

<b>Name of the Course</b>	<b>Extent (CPL/The whole course) [ECTS]</b>	<b>Code and # of Students in CPL</b>	<b>Tasks in CPL</b>	<b>Other parts of the Course</b>
Pedagogy of elementary school Science	3/9	EST 8	Workshop design and instruction	Lectures, hands on workshops, Exam
Pedagogy of Physics	3/7	SPT 4	Workshop design and instruction	Lectures, Finnish as a second language project
Research Methodology and Communication	1/3	SPT 4	Teaching experiment	Lectures
Instructed Advanced Teaching Practice	1/7	SPT 4	Data collection	Lessons in the Teacher training School
Visual Arts and Pedagogy	1/7	EAT 11	Exhibition guide	Methods of visual arts and pedagogy
Art Workshop	1/1	EAT 9	Exhibition guide, workshop design and instruction	Lessons and auxiliary program.

The SPT students and the EST and EAT students formed four integrated groups of four students (1 PST and 1-2 EATs and ESTs in each). The four SPTs integrated three of their courses in CPL. For nine students, the CPL-project was an optional Art Workshop course including also introduction to the exhibition and lessons and other auxiliary program and guiding of several groups. In addition, eleven first-year elementary school student teachers taking the Visual Arts and Pedagogy-course acted as exhibition guides: they participated in a two-hour introduction at the museum, two hours of guiding groups of pupils and were given extra independent work materials making them better acquainted with the artists and their work.

## The exhibition

The Exhibition Checkpoint Leonardo was displayed in the Jyväskylä Art Museum 15.3.-28.4.2013. The six artists of the exhibition were chosen among those who are known to employ science in their works. The project included an exhibition café where the audience could turn the phenomena of natural sciences into artistic experiences (see below for the workshop descriptions). During the display period, also a fleet of 8 general lectures were given by artists, scientists, education pioneers and an art historian. The brand of CPL propagates now in University towns in Finland (Tampere, Oulu, Joensuu).

## Thermo Image Inquiry

The starting point of this Inquiry was Terike Haapsalo's artwork "In and Out of Time", in which a calf, deceased shortly before recording began, was filmed parallel with a visible light (normal) and infrared (thermo) camera. The original teaching/learning intervention idea of the students was to use a thermal camera to record dynamic changes of different objects such as a hot water bottle, a thermal plate etc. However, thermal cameras were too expensive for the budget of the project and the group tested a possibility to use an infrared filter on the lens of normal digital video camera. The filter was fabricated by just buying a slide film from a photo shop and giving it immediately back for development. Positive slide film develops opaque for visible light (black) while unexposed but the material needs to pass infrared as it would otherwise melt in front of a hot lamp of a slide projector. However the quality of this kind of filter was not good enough for the students' purposes and they ended up using a raster scan of a thermal image using normal infra-red thermometers. In the inquiry, pupils raster scanned the body of a classmate or, alternatively, their own hand. They then arranged their color pencils according to what they experienced the temperature order of each color to be. Finally they divided the measured temperature range into classes per color to draw a thermal image of their measurement. The objectives of this inquiry were to understand the concept of color temperature, modeling and visualizing the observations of the nature, the resolution of an image and thermal conductivity and insulation. A common misconception among the pupils came up in this inquiry. Most of the students believed that the temperature measured on a spot covered by clothes would be higher than on a naked skin. The thicker the cloth, the higher the temperature should be – according to their thinking. This inquiry seemed to be effective in helping them reason how clothes and thermal insulation work.



Figure 1. In Terike Haapsalo's artwork "In and Out of Time" the body of a dead, cooling calf has been imaged simultaneously by a video camera and infrared camera (left). In the workshop, students first measured temperatures on spots of their bodies by an infrared thermometer (middle). Finally they chose colours representing different temperatures and draw a raster thermo image according to their measurements.

### **Red cabbage art**

This workshop was based on the artwork by Jeanette Schäring from Gothenburg, Sweden. It was an arrangement of transparent containers of water from different urban sources, which turned to hues of yellow due to a natural indicator and the acidity of the water.

In the workshop, pupils inquired the acidity of common domestic chemicals and registered the color changes for each liquid when added into red cabbage juice. After that they were given a piece of paper saturated with red cabbage juice to create art using the domestic chemicals as dyes.

### **Kinetic artwork by electrolysis**

This workshop was based on an installation by Päivi Hintsanen, which gradually changes the color of pieces of metal oxidizing in acid tanks. The pupils tried electro coating different materials and inquired their color changes in copper sulfide. The successive workshops constructed a progressive kinetic artwork from the materials. The core idea of this workshop was that a single color perception may be due to different phenomena in the nature, and may origin of the properties of the bulk material or its size: oil film on a sub phase of water, fluffy wing of a butterfly or a spray of water to make a rainbow. Another objective of this workshop was to learn a method to fabricate color pigments.

### **Sensory perceptions**

The starting point to inquire the nature of sensory perceptions was the series of cubistic paintings by three artists: Mikko Ijäs, Liisa Lounila and Sami Lukkarinen. In the workshop, pupils constructed visual models of sensory data gained by an optical microscope, touch, and smell. The optical microscope was used to inquire the raster character of printed images on newspapers. They were compared to the cubistic paintings and the concept of resolution was discussed. The pupils also practiced acquisition of data from a “topographical black box” by touching. The box included materials of different hardness and thermal capacity, like cotton balls, stones, hairbrushes etc. The students were then to represent the result of the manual scanning on a piece of paper. The objectives were to learn the advantages and the disadvantages of a model made by mechanical probing compared to a direct visual image. The advantages reported included the data of hardness, temperature and topography, and no need of illumination. The disadvantages were the lack of sense of color and poor lateral resolution, among others.

The third part of this workshop was to smell vials of different samples, such as garlic and tar. The original idea was to construct a lateral “odor black box” of different smells in a pizza case with a matrix of holes on the cover. However teacher students considered this task too difficult for 6<sup>th</sup> graders, and in the final version they drew their experience of smelling each different vial on a paper for other pupils to interpret. The core ideas to learn in these inquiries were that gaseous substances are mixed and the particles will drift to nose to generate a sensation. Also the memory and the limitations in the resolution of human sense of smell compared to dogs, for example, were discussed.

### **Teaching and learning in the new surrounding – a day at the art museum**

Almost forty 6<sup>th</sup> grade primary school groups from Jyväskylä (about 1000 pupils) visited Check Point Leonardo workshops and the guided exhibition tour. Each group participated

in a single workshop. The program at the art museum took altogether four school lessons (1 lesson is 45 minutes). The teachers were able to load the materials of the exhibition and the workshops from the internet in advance.

### Impact of the Project

In the CPL project we were interested about the student teachers' ideas of the nature of science and art and how do they change after participating this project? To find this out we asked the student teachers (N=32; 20 EAT, 8 EST and 4 SPT) to write down their ideas on three questions prior and after the project:

- 1) Describe the process of arts
- 2) Describe the process of science
- 3) What is similar and what is different between science and arts

We searched the NOS core aspects for 6<sup>th</sup> graders from the pre-project answers in questions 1 and 3. This analysis is based on the comparison of expert and novice group responses to the VNOS-B questionnaire in [7]. Sentences like “science is based on empirical investigations” were interpreted to be in agreement with expert response, while a claim like “there is no place for creativity in science” is an example of an opposite (to expert) response. These analyses were carried out by three of the authors (MA, AL and AL) independently and those suggested responses to an aspect which were noticed by just one of us (20%) were rejected. Table 2 shows the distribution of the relevant (at least two marks) responses.

Table 2. The NOS aspects mentioned in student teachers' pre-CPL essays. The expert response refers to ideas similar to the majority of experts and the opposite response to ideas that disagrees with those in [7].

NOS Aspect	Expert response	%	Opposite response	%
<b>Empirical nature of scientific knowledge</b>				
Observations used to make scientific claims	13	41	0	0
Science does not rely solely on empirical evidence	7	22	1	3
Supports rather than proves scientific claims	1	3	1	3
<b>Inference and theoretical entities in science</b>				
Inferential nature of atomic models	5	16	0	0
<b>Nature of scientific theories</b>				
Theories change due to new evidence	4	13	1	3
Theories change due to new ways of looking at existing evidence	4	13	2	6
Explanatory power of scientific theories	6	16	0	0
Theories are well-substantiated	2	6	0	0
Theories provide a framework for current knowledge and future investigations	2	6	1	3
<b>Scientific theories vs. laws</b>				
Nonhierarchical relationship	0	0	0	0
Laws may change	2	6	2	6

<b>Creativity in science</b>				
Creativity permeates scientific processes	3	9	5	16
No single scientific method	1	3	1	3
<b>Subjectivity in science (theory-ladenness)</b>				
Differences in data interpretation	1	3	0	0
Science is necessarily a mixture of objective and subjective components	3	9	3	9
<b>Social and cultural influences</b>				
Science as a culture within itself	0	0	1	3
Peer review limits subjectivity	0	0	0	0
Society as an influence on science	0	0	0	0

From these answers we nominated three types of student teachers: the novice teachers represent the ideas of the novice group and the expert teachers represent the ideas of the expert group in Ledermann's investigation. In addition, there are in-between student teachers, whose ideas agree with the expert groups' ideas, except for those regarding the subjectivity and the role of creativity in science.

According to a sample novice teacher (EST) pre-CPL answer a scientific process was "a phenomenon which typifies the reactions of the world", while in the post project essay "these phenomena occur according to laws of the nature". In the pre project essay, (s)he makes the claim that "science is concrete and art is abstract". After the project, however, the both are "generated by a reaction which has been observed and recorded consciously or unconsciously and may be represented according to one's own desire". We interpret here a developing understanding of the Kant's higher cognition or "anschauung" and also the effects of the social and cultural context in which scientific investigations are embedded.

An "in between" student teacher (SPTa) shows understanding the empirical and tentative nature of science already in the pre project essays. However in these "science must be based on the reality, while art may be whatever". In the post project essays there is a new step in the scientific process, "trying to understand" which may show the use of creativity during a scientific process. Also the "whatever" has now turned into "more freedom" and evaluation has become a part of the process of art.

An expert student teacher's (SPTb) pre-project ideas followed the expert groups ideas in the Ledermann's investigation also in the aspects where the expert group was not in consensus: the effects of the social and cultural context. This expert student teacher used the concept of world view: "In the scientific process, the researcher's own world view should not affect to the research, while in the arts the point is to interpret phenomena through artist's own world view". In his post project essay, this expert student teacher writes: "both hypothesis and the initial idea (or inspiration) of the artist are visions of something which does not exist yet".

## **Conclucions**

Only 41% of the students to teach science later in their careers, routinely noticed it as an empirical subject. This alarming low number is probably due to the selection system to our elementary teacher education, which emphasizes applicants' verbal skills over reasoning. The numerous thoughts of science not allowing creativity reflect naive conceptions of science as a set of eternal truths to be distributed in school education. In CPL we wanted to challenge these stuffy attitudes.

The very open nature of the assignment was a little confusing to some of the student teachers, but the written information of the artworks and the artists was considered very helpful. After a little stress at the beginning, the groups learned to self-organize their work well and the atmosphere was remarkably better in every group than in most of the groups of traditional courses, according to our experiences. The active learning combining science and art rose spontaneous questions in pupils, which are quite rare in Finnish schools. In many feedback sheets the active atmosphere was suggested to be due to the different learning environment. Some of student teachers considered the project too demanding and long-lasting, but the majority of them appreciated the authentic task, environment and the responsibility of the project over the efforts. The student teachers appreciated that they were given free hands and the authority.

The in-service teachers were quite passive and kept on the background, leaving their pupils to work alone. We have also observed this problem in our earlier science road show projects: teachers are active leaders in their classroom but they stay in the background while outside the school environment. The age of children suited very well for this kind of combined inquiry of something visible and something imaginable.

Good practice and ideas are distributed on the project web site Checkpoint Leonardo [www.checkpointleonardo.fi](http://www.checkpointleonardo.fi) (unfortunately only in Finnish so far).

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