Learning in Science Education Across School and Science Museums – Design and Development Work in a Multi-Professional Group

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English abstract

The MIRACLE project aims to design and develop learning activities in science that will be used across schools and museum settings. A combination of digital technologies plays a vital role in bridging these institutional contexts. Cultural Historical Activity Theory will be used to analyse how the multi-professional project group orients to designing for science learning. In the analysis, we identify three contradicting orientations: experience, emotional involvement, and conceptual understanding. We discuss the implication this has for the further design work.

Keywords: Learning in science, science museum learning, Cultural Historical Activity Theory, design intervention

Introduction

Today, social institutions outside schools make systematic efforts in providing learning activities. As socio-technical networks become an important means of gaining, sharing, and generating knowledge across institutional boundaries (Facer & Sandford, 2010) we will likely see a shift in coming years towards a more diverse and complex learning landscape, where learning takes place across a wide range of sites and institutions. Facing these challenges is the core of this special issue on the extended classroom.

This article is concerned with the extended classroom concept, and discusses the challenges that a multidisciplinary group faces when designing science-learning activities that cross the institutional settings of schools and museums. The project Mixed Reality Interactions Across Contexts of Learning (MIRACLE) aims to increase students' interest in and conceptual understanding of science by connecting learning activities in science education at upper secondary schools to activities at a science museum.

Research literature has paid scarce attention to transcending the contexts of schools and museums. Kaptelinin (2011) argues that designing technological support for meaning making in museums is promising for enhancing museum experiences across contexts. In MIRACLE, we will design and develop learning activities, mediated by different technologies, through which students will be introduced to relevant curriculum-based themes as a pre-visit activity at the school, engaging in science activities at the museum, and later elaborating on their reflections as a post-visit activity back at school.

The project brings together a multi-professional group of museum conservators, exhibition designers, learning scientists, interaction designers, computer scientists, and animation specialists to design and develop these learning activities. We consider this multi-professional group as vital to design technology-mediated learning activities in and across schools and museums. Based on project documents and video data gathered from a kick-off workshop, we have derived three empirical research questions related to the issues regarding multi-professional collaborations. First, we investigate the project members' orientations, to consider what they take into account when talking about designing for science learning in and across schools and museums. Our first research question is:

> *'What do the members in the multi-professional team highlight when designing for science learning in and across schools and museums?'*

Second, we will distinguish possible tensions in what the variations in designing for science learning imply for the project members. We consider these variations as productive for the design and development of learning activities in the sense that these might bring forward the best from each institutional setting. Our second research question is:

> *'What types of tensions can be identified in the multi-professional project group?'*

Moreover, in a more analytically motivated manner, we would also like to identify how these orientations and expected tensions can be dealt with in further work with design and development of the learning activities. We are planning an educational trajectory during which students will be exposed to some issues in science as a pre-visit activity at school, followed up by different activities during their museum visit, and elaborated on when they have returned to school. This constitutes the basis for our third research question, which we will take up in the discussion and conclusion part of the article:

> *'What implications do these orientations and tensions imply for the further design of learning activities across school and the science museum settings?'*

As a theoretical basis, we will use Cultural Historical Activity Theory (CHAT) and the concept of object-oriented activity, which provides an entry point to the analysis of how members in the multi-professional group make sense of the general aim in the project. In collaborative work, the members carry with them their traditions and norms, and different interests and motives for participating in the work. Tensions in orientations are thought of as natural features in activity systems and are considered positive in the sense that they hold the potential for organizational improvements (Engeström, 2001).

Following this introduction, we review a selection of literature on science learning research in schools and museums. We then give an account of how we understand the notion of 'object' from an activity theory perspective. This will be followed by a description of methods, and the empirical analysis of some aspects in the data collected from a kick-off workshop. We conclude with a discussion and some final remarks.

Review of science learning in schools and museums

Research in museum learning tends to emphasize differences between formal and informal learning, operating with the premise that informal learning uses authentic objects and is based on experience, while formal learning uses representations and is based on texts (Paris & Hapgood, 2002). Fifteen years ago, it was recommended 'future research in science education should focus on how to effectively blend informal and formal learning experiences in order to significantly enhance the learning of science' (Hofstein & Rosenfeld, 1996, p. 107). A review of literature on science learning in schools and museums indicates that there is scarce research on bridging the contexts of schools and museums.

Learning research related to science is primarily concerned with learning in the classroom context. A large part of this research focuses on how students learn disciplinary concepts rooted in the curriculum. Research reports that students frequently have difficulties when making meaning of disciplinary issues in science, and their understanding tends to be fragmented (Arnseth, 2004; Krange, 2007; Roschelle, 1992). Moreover, teachers are likely to emphasize the performance of tasks rather than going into detail and helping students to synthesize scientific concepts (Furberg & Ludvigsen, 2008; Krange & Ludvigsen, 2008). Another serious concern is that students tend to choose disciplinary domains other than science (Vetleseter Bøe, Henriksen, Lyons, & Schreiner, in press).

In the field of learning in science museums, there is a substantial body of research on field trips. Much of the literature has attempted to measure learning outcomes, and find that field trips can have a positive impact on learning of facts and concepts (Anderson & Lucas, 1997; Bamberger & Tal, 2006), as well as having social and affective learning outcomes (Csikszentmihalti & Hermanson, 1995; Meredith, Fortner, & Mullins, 1997). Research also provides insight into factors that can affect the school trip learning experiences, such as social interaction between students on the museum visit (Dierking, 2002; Price & Hein, 1991), and the impact of prior knowledge (Beiers & McRobbie, 1992; Falk & Storksdieck, 2005). Similarly, studies of science learning in schools have found that students have difficulties understanding relevant meanings from visual and spatial representations of science because the ability to interpret a physical or digital representation is dependent on prior knowledge (Schnotz & Lowe, 2008). It has also been documented that the structure of museum experience influences what students remember and understand (Anderson & Shimizu, 2007; Pierroux, Krange & Sem, in press). Some studies suggest that highly structured experiences, such as guided tours and worksheets oriented mainly to school curricula, diminish the students' engagement in the museum context (DeWitt & Storksdieck, 2008). In other words, there is a danger of making the museum visits too 'school-like'. Another concern is that teachers hardly ever define their goals for the museum visit, and rarely plan or conduct pre- and post-visit activities (Griffin, 2004). Studies concerned with the effects of post-visit activities have nonetheless found that extensive preparation and follow up to a museum visit support the development of scientific conceptions (Anderson, Lucas, & Ginns, 2003; Anderson, Lucas, Ginns, & Dierking, 2000). Even though these studies focus on learning in different contexts, they still treat formal and informal learning as dualistic entities. Instead of seeing schools and museums as dualistic entities, we view them as different social practices.

CHAT: making sense of the object

In CHAT the institutional settings of schools and museums are understood as different social practices or activity systems with different historical objects, functions, and norms and directions for their work. What counts as knowledge, or what kind of knowledge is 'seen' as valuable, differs between activity systems. Learning is pursued differently in schools and museums. It is therefore important to design for learning trajectories that cross the boundaries between activity systems. CHAT offers a framework for analysing structures and dynamics in and between activity systems, and how they change (Engeström, 1999).

In today's complex character of work in organizations, professionals operate in and move among multiple parallel activity systems. It is, therefore, necessary to empirically focus on dialogue and negotiation between networks of interacting activity systems (Engeström, 2001). We recognize design and development work as an object-oriented activity in which actors from different professions collaborate to negotiate a joint understanding of learning activities between school and museum. The notion of object can thus be used analytically to examine how the participants in the project group seek to orient themselves towards the demands that emerge in the design process. The object affords an empirical analysis of how an activity is structured over time and the human, institutional, and material resources that delimit such activity. In CHAT, the object has a dual nature: it is realized through activity, while, at the same time, the activity is formed by the actors' notions of the object (Kaptelinin, 2005). When the object is realized through activity it refers to the material quality of the object, which emerges in various instantiations as it is constructed or refined (as an equation, an essay, a building). However, the object also has an ideational aspect, which refers to how it is made sense of by the actors in the activity. The object's role as a 'sense maker' affords an analysis of what the participants do, why they are doing it, and the direction that the activity takes (Kaptelinin, 2005). This is facilitated and constrained by historically accumulated constructions of the object: how tasks have been solved earlier, and how tools and digital representations have been understood and used in the different activity systems. The object is not fixed, but is constantly evolving and changing. In the case of the multi-professional group trying to make sense of how to design for learning activities across schools and museums, the members struggle to construct a materialized representation while they also struggle to conceptualize what learning in science means. This implies that to succeed in their collaborative work effort, they need to negotiate different object orientations to achieve a potentially shared or jointly constructed materialized object. This collective formation of new mediating concepts is designated 'boundary crossing' (Engeström, Engeström, & Kärkkäinen, 1995).

This article is the first in a series focusing on design and developmental work. In the case of the empirical study that follows, we will make use of the object to examine the various participants' efforts at understanding and presenting a phenomenon or idea, and the implication this has for the further design of learning activities across schools and museums. This is important knowledge for our upcoming attempts to follow the trajectory of object construction over time.

Study descriptions

The empirical illustrations in this article are gathered from different kinds of project documents, the institutions' websites, and the kick-off workshop arranged at the beginning of October 2010. The included documents are the research project proposal, the consortium contract, and the provisional educational plan and exhibition plan. The researchers wrote the project proposal, with contributions from the different partners where their institutions are presented. The consortium contract was also written by the researchers, but the formulations about the partners are based on the project description and were confirmed by the partners while signing the contracts.

The kick-off workshop was a two-day session. The first day took place at The Norwegian Museum of Science and Technology (NMST), and the second day at InterMedia, University of Oslo. An important part of the workshop was to get to know each other, constitute the MIRACLE participants as a group, and to have a joint effort to identify ideas for science learning activities for the exhibition 'Power for Norway' and technological solutions and combinations. All partners were invited to introduce those projects or research findings that they considered relevant for the MIRACLE project. Different technological possibilities to support the learning activities were introduced, tried out, and discussed. Other main activities were group work and brainstorming. The aim was to open up different possibilities and arguments for how to design and develop the learning activities in and across the two institutional settings and across different technological solutions.

The design and development group consists of four partners: NMST, the architecture firm CoDesign, Storm Studios AS, and InterMedia at the University of Oslo. From NMST there is a museum conservator, with an educational background in history, a doctor in science who is the project developer at the Science Centre, and the head of the science centre, who is educated within science and education. In addition, two exhibition designers from CoDesign and an animation expert from Storm Studios have central roles in the design and development. The participants from InterMedia consist of four learning researchers, an interaction designer, a computer scientist, and designers and developers. A group of teachers will also be central actors in the multi-professional group. They did not take part in the kick-off workshop, but will participate in future workshops. Storm Studios and the designers and developers from InterMedia are not present in the data selected, since this article does not discuss different choices for digital representations or technologies, which is their main contribution to the project. For the purpose of this article, we have chosen to focus on the NMST, the architecture firm, and the researchers from the University of Oslo. The data are based on the project members' plenum presentations at the kick-off workshop that were video recorded. In total, ten hours of video recordings were produced from the workshop. The plenum presentations were selected for the purpose of this article, and these recordings were transcribed.

The data from the presentations were in English, and the transcripts are based on what the project members actually said. The first and the second data types have helped us describe the multi-professional nature of the project group and how its members make sense of the object when they argue about how to design and develop learning activities across school and museum.

The participation of two of our colleagues as researchers in the group that we are studying is an issue about which we need to be aware. Our own voices should not be biased compared with the other voices that are presented. Practically, this means that we are *not* looking for some kind of normative idea about the right opinions of how to design and develop learning models in science, but rather to identify the different orientations, how these are balanced, and how they can be taken into consideration when designing for a learning trajectory crossing school and the science museum contexts. We have used our socio-cultural research community to qualify the objectification of our analysis to make sure that we deal with the different voices equally.

Analysing object orientations in the design and development work

In the MIRACLE project, we aim to design models of science learning where digital technology can bridge the school and museum settings. These are complex design challenges beyond the limits of each profession's existing knowledge. As part of the application process, a project group was constituted to enhance the exchange of information and ideas across boundaries. The group comprises members of professions with very different training, ideology, and status, who were invited into the project because of their specific knowledge expertise. In her introductory presentation of the workshop, the project leader explains that the designed learning activities will relate to the upper-secondary school science curriculum and the 'Power for Norway' exhibition at the NMST. The general objective of the project will mainly be worked out in small groups that have responsibility to develop specific plans. The researchers will develop an educational plan; the computer scientist, the designers and developers from InterMedia and Storm Studio have the responsibility for a technological plan; and the museum and the architecture firm will develop an exhibition plan. Through the project, meeting points between these groups will be arranged to identify and specify how these different plans interconnect.

How learning in science in and between school and museums is understood in the project is explained in the project description:

> *'In museums you see an artifact or a process and read the poster. At school you read the text-book, listen to the teacher explain and look at a model. In contrast, we learn best when we experience something and when we can reflect on our experiences with others in focused and supported discussions. We learn best when we can interact with dynamic representations and models of processes and phenomena' (Project description, p. 1).*

This extract demonstrates how learning in schools and museums has traditionally been understood (see e.g. Paris & Hapgood, 2002), and how MIRACLE aims to challenge the analytic distinction between museum and school activities. However, the project description is not clear on how one should design learning activities that cross the boundaries between these settings. Generating ideas on how this can be done should be reflected on in focused and supported discussions with others. To succeed in the aim of designing learning models that combine learning in schools with museum activities, the project group has to embrace a procedure that enables all participants to contribute and share information, ideas, and subject-specific knowledge. CHAT studies within various organizations and professions have shown that exchange of knowledge and information between activity systems is necessary but challenging (Engeström, 2008). The purpose of the following section is to clarify the different object orientations to designing for learning activities in science education and how these are potentially contradictory.

In the following, we will be concerned with how three of the central actors make sense of the object.

The Norwegian Museum of Science and Technology (NMST)

The NMST is planning to upgrade, expand, and renew the museum's energy exhibitions in the coming years. This renewal will combine today's energy exhibition with the science centre at the museum. In the consortium contract, the museum presents itself in this way:

> *'The museum has long experience with preparing and presenting examples of breakthroughs in science and technology, from both a historical and contemporary perspective, and which is visible both in their permanent and temporary exhibitions" (Consortium contract).'*

The aim of an exhibition is to present a knowledge domain to the visitors. The temporary exhibition 'Climate X' was the first attempt to renew the museum and offer different kinds of experiences for museum visitors in general and schools in particular (the exhibition plan). The aim was to communicate climate changes with the use of several spectacular manifestations. Ice blocks and water pools were used indoors to show the effects of climate change (consortium contract). The exhibition had different kinds of interactive exhibits where the visitors were invited to 'play, feel, react, discuss, argue, cast their votes, in addition to the normal reading and looking at pictures' (plenum presentation, museum conservator). The underlying characteristics are, therefore, an emphasis on multiple representations where displays are presented to evoke a variety of responses.

The museum conservator explains that they took many steps forward as a museum with this exhibition, both in terms of positioning themselves as a museum and rethinking exhibition design. They feel confident that they managed to design an exhibition that gave visitors knowledge and engagement about climate issues. The key to success is described as being due to the close collaboration with the architecture firm. While in earlier projects they had turned down ideas and designs from the architects because they seemed too playful and too risky, they decided to be true to the basic concepts from the architects in Climate X.

The new 'Power for Norway' exhibition will focus on the electrification of Norway around 1900, with an emphasis on the political discussions concerning the rights to waterfalls and industrial development as a motor in the electrification and diffusion of the technology into the homes all over the country (exhibition plan and conservator's presentation). With this temporary exhibition, they will continue to develop the ideas of exhibition design from Climate X. Their preliminary ideas for this new exhibition are: to design an interactive map; make the visitors, and especially students, active in understanding the relation between the producer, distributor and consumer of power; and bring elements of nature into the exhibits by installing a waterfall in the museum area. They want the exhibition to be 'playful' and they want to use the nearby river to provide an aesthetic dimension to the exhibition (exhibition plan and observation from kick-off workshop).

In Climate X, they worked with over 1,200 groups of students who worked with tests and assignments developed by the museum educators before, during, and after the museum visit. As a part of their renewal of the museum in the coming years, they are planning to expand their communication to students. Collaboration with schools and the MIRACLE project thus supports the aim of developing and improving plans for students' learning activities at the museum. This is done by the use of new technology to 'strengthen the relationship between schools and the museum with the aim to engage and involve the students, and in this way improve their learning outcome' (the exhibition plan).

Experience is also emphasized in the exhibition plan, consortium contract, and conservator's presentation. In the presentation, the conservator explains why a good exhibition experience is so important:

> *'So even those who only remember the experience of being in the room – that is also a way of getting a message through. Maybe they didn't learn anything about the carbon-cycle, or the greenhouse effect by being in the room, but a museum exhibition like this sticks, it gives an opening, an awareness or curiosity, that makes it easier to get more knowledge and take part in discussions and so on' (museum conservator's presentation).*

The documents and presentation from the museum conservator at the NMST describe a museum that is in the process of a makeover of its museum exhibitions. In this process, they emphasize the power of interactive experiences that stimulate engagement and discussions. If we look more closely at what this makeover means, we will argue that the object orientation of NTSM is science museum visits, understood as interactive experiences. Interactive exhibits lead to high quality museum experiences and will influence their in-museum learning.

The Architecture Firm

Another central representative in MIRACLE is CoDesign, a Swedish architecture firm that has specialized in designing museum exhibitions and has designed several spectacular projects in the Nordic countries and elsewhere.

The exhibition designer emphasizes that in architecture firm's work, they try to design for ways of interacting in museums that are different from how interaction in museums has traditionally been represented. In his presentation at the kick-off workshop, the exhibition designer uses Climate X as an example. He explains how they designed the exhibition, what exhibits they used and why, and what this means for the 'Power for Norway' exhibition. The interactive exhibits should touch the visitors' emotions in order to create engagement, as in Climate X where the visitors could wade in water, touch the ice, and get rain on their heads. They were also invited to play, discuss, and cast their votes on central issues concerning climate. The results were sent to the media and to politicians so they would be informed about what people think. On the firm's webpage, CoDesign explains the idea behind Climate X:

> *'The concept for KlimaX to create an exhibition that touches the visitors instead of just informing them; an exhibition that triggers more senses and leaves an ineffaceable memory; an encounter that goes to the gut rather than the brain and makes people remember the main message the day after the visit; an experience that will make its way into the small talk around dinner tables and coffee machines. That was our aim' (http://codesign.se/klima-x).*

The idea behind this exhibition was, in other words, to design an exhibition where visitors use more senses than just listening and reading, and they especially aimed to reach the visitors' emotions. For this work, the exhibition was voted the best Nordic Exhibition Concept in 2009 and received an international award for Best Visitor Experience. In his presentation at the workshop, the exhibition designer explains why it is so important for museums to engage the visitors:

> *'You don't want to read an A4 of text, we want some kind of emotional opener. The door opener to the intellect is here [points to the stomach]. This is really hard for some people to accept in the museum world and we are so sure that this is the only way to go about it. That you cannot find all those teenagers, that we cannot reach our intellect without touching our stomach. You can select so much information, but it is only when you get emotionally engaged that you start to be interested in the information' (Exhibition designer's presentation).*

When designing an exhibition, the architecture firm focuses on creating different kinds of interactive exhibits. Its aim is to create exhibits where visitors become emotionally engaged with the presented subject. Both on his web page and in the presentation at the kick-off workshop, the exhibition designer emphasizes that emotional involvement is the basis for the uptake of information. We would therefore argue that the object orientation of the architecture firm is design of representations, emphasizing emotional involvement.

University of Oslo

According to the consortium contract, the learning researchers in MIRACLE bring with them 'long research experience of design and use of digital learning resources in education and studies of learning in and between such institutional contexts as schools, work, and museums'.

The learning researcher and the interaction designer giving presentations at the workshop were concerned about how to design for learning about energy and how technology can be used to support learning in specific ways. Furthermore, they drew the group's attention to research findings that demonstrate that students have difficulties making sense of the principles of science, which means that they lack conceptual understanding of the issue. The learning researcher emphasizes that scaffolding and support from a teacher and the virtual environment have to be available for the students when they need it. It is also emphasized that reflection and assessment must be facilitated in the design. The learning researcher suggests leaving learning traces in the environment that can be picked up by the student. This will facilitate the circle of reflection and action/experience, thereby bridging school and museum activities. Both the learning researcher and the interaction designer referred to the exhibition designer's focus on emotional engagement. The learning researcher agrees that the museum activity should be based on experiences and engagement, but emphasizes that experience and understanding is difficult to combine. His concern is that it is not certain that students will interact with the exhibits in the way that is anticipated in the design. A simulator in the present energy exhibition at the museum is mentioned as an example, and it is argued that when students approach the simulator, their focus will probably be on winning the task, with the result that the science in the experience disappears. In other words, he says that it is not enough to design exhibits with a high level of interactivity, as these will not automatically lead to conceptual learning. These experiences need to be brought back to school where the students reflect on the experiences; otherwise it remains an experience that cannot be considered learning. The interaction designer refers to the exhibition designer's argument to clarify the researchers' perspective on learning:

> *'I believe that to be right [the door to the intellect is emotions], but it shouldn't stop there, it should continue. Of course, you have to be motivated and engaged in a way to try to explore relations*

> *without very precise questions just to get the feeling of things. For example, what we did at the climate simulation [this is a simulation that was designed and developed as part of the EU-project SCY and that has been demonstrated for all the workshop participants]. But then you need at some point, to get over to a more conceptual reflection of what really is. And the grading issue has to be reproduced at some point. The teacher will ask them at some point, "can you explain the CO_2 cycle to me?". "I just did that in the simulator" is not good enough, you have to put it in a different context and explain' (interaction designer's presentation).*

In his statement, the interaction designer confirms that it is important to find strategies to motivate and engage the students. However, to demonstrate learning, the students have to be able to explain the scientific principles behind what is experienced. Based on the presentations of the two researchers, the project description, and the consortium contract, we argue that the researchers acknowledge experience and engagement as important motivational triggers, but proposed that this cannot be considered learning. The researchers' object orientation is learning science, with an emphasis on conceptual understanding.

Summing up the analysis – identifying object orientations and tensions

The analysis gives an historical account of how three different professions orient to the general objective of the project, designing for learning activities in science across school and museum. The three institutions are all concerned with this objective, but the analysis shows that they have different orientations. Independent of the MIRACLE project, NMST is in the process of renewing the museum exhibits that both engage visitors' moment-by-moment and support science learning. The science museum's concern is its role in promoting and re/presenting science to students and to other visitors, and argues that this requires a change in the relationship between visitor and exhibit. The concern is to design exhibits that do not just entertain, but which also facilitate science learning (Allen, 2004). The museum staff focus on opportunities for involvement, where students can experience science by exploring, experimenting, hypothesizing, and interpreting exhibits. Such activities have the potential of supporting learning. We would argue that the museum is concerned with designing for *interactive experiences*, or what Allen (2004) calls 'minds-on', as well as 'hands-on' (p. 25).

The orientation of the architecture firm is much the same as that of the museum. This is not surprising, since the museum awarded CoDesign the design of Climate X and the forthcoming 'Power for Norway'. Both argue for the importance of involvement when designing for learning in museums. However, they have different orientations toward involvement. While the conservator is concerned with designing exhibits that support interactive experiences, the exhibition designer is concerned with designing exhibits that support *emotional involvement*. We recall that the exhibition designer argued that the intellect is evoked by emotions. The role of affect has been particularly important in science learning in museums, with some research arguing that the chief impediment and motivator for learning is not cognition but affect (Alsop, 2001).

Not surprisingly, the analysis shows that the learning researchers have a different orientation. As educationalists, their concern is that students in science education should reflect on the principles of science. They confirm that quality experiences and emotional engagement can be central motivators for learning; however, this is in the background of their argumentation. Their primacy is designing for learning environments that support the students in understanding the principles of science (Arnseth, 2004; Krange, 2008; Vygotsky, 1978). Their object orientation can, therefore, be seen as *conceptual understanding*.

In many ways, this analysis sharpened the differences between various object orientations where the participants mostly made statements about their concerns and interests to the project. This is not surprising since the collaboration between the activity systems in this setting was based on presentations from the representatives on their interests in the MIRACLE project and was not open for any discussion of concept formation. In a study of boundary crossing, Engeström et al. (1995) found that it is difficult to cross boundaries by means of meetings alone, without identifying concrete problems to solve. Identifying these boundaries can be said to be the next step of our project.

Discussion and concluding remarks

The aim of this study has been to better understand the design work in a multi-professional group. The overall project aim is to design and develop learning activities in science that will be used across schools and museum settings. It is vital to identify the members' different orientations, and how these contradict, to get the best out of each partner in the future collaborative work.

The first aspect of the discussion is linked to the question of what characterizes the different object orientations among the members in the project group. We argue that the members are all oriented to the generalized aspect of the object activity, as it is described in the project proposal, but they conceptualize and enact the object in different ways, depending on the histories and traditions that each member carries with him/her (Engeström, 2001). Overall, the members consider it necessary to design for activities that improve the students' learning in science, whether this takes place at school or at the museum. Moreover, the members also agree that this could be accomplished by connecting museum experiences to pre- and post-visit activities at the school. However, there is tension in how to design for activities that improve learning in science: should we design for interactive experiences, emotional involvement or conceptual understanding? It is not our intention to make a simplistic picture of the members' object orientation. The museum staff is centrally concerned with creating exhibitions that are engaging and inviting, but at the same time are close to the curriculum and stimulate discussions around scientific phenomena. However, interactive experiences are in the foreground. The researchers, by contrast, place the problem of conceptual understanding in the foreground, and museum experiences and emotional involvement in the background. What is most important for the researchers, which we will come back to, is that neither project description nor any of the participants are foregrounding how to design for activities across school and museums.

Kaptelinin and Nardi (2006) argue that in collaborative work, it is expected that the various members have different motives related to the same object. The conflicting conceptualizations of the object can be understood by taking the participants' diverse interests and motives for being involved in the activity into account.

The motives of the museum and architecture firm are concerned with the museum activities and are based on a critique of traditional exhibitions planned around clusters of hands-on displays about science and scientific principles. They share an interest in creating spectacular exhibitions that involve, engage and motivate. However, their motives differ. One of the most important activities for NMST is school visits. They collaborate with many schools, and they are concerned with how museum experiences are picked up by the students, due to limited pre- and post-visit activities carried out by teachers back at school. School visits can therefore be seen to be their object motive. The motive of the architecture firm is the design of spectacular and innovative representations, which give them a good reputation and job opportunities. The researchers' motive is first and foremost concerned with school activities and an interest in supporting students' conceptual understandings of scientific phenomena. This interest is related to previous research emphasizing students' problems with conceptual understanding when participating in, for example, science education (see eg. Krange, 2008).

These orientations and motives have some important consequences for the further design of learning activities, as collaborative work between experts from different professions is vital to creating a learning trajectory across schools and museum. Multi-professional work is challenging because it requires shared knowledge among the members of each other's practice, and it implies negotiation across different fields of expertise. Based on the analysis, we argue that the problem is not resistance to change, which is usually the main problem when trying to initiate educational reforms (Jahreie & Ludvigsen, 2007). The project members can agree on the importance of experience and emotional involvement in increasing the students' interest in, and conceptual understanding of, science. Despite their accord on the importance of the three, the different orientations to designing for learning activities in science are seen as separate, and the integration of these concepts across schools and museums is not discussed in the workshop or clarified in the project proposal. The analysis of this article elucidates several questions that the project group needs to consider in future workshops: When designing for learning, should experience or scientific reasoning be the focus, or perhaps both? Should there be degrees of emotional involvement in school activities, and, if so, how much? Should a representation of an energy process be a complex and realistic representation of energy or a more simplified representation? Should such a representation trigger conceptual understandings or emotional involvement? Should it be localized in school, in the museum, or in both places? Should the representations in school foster conceptual understanding while the representations in the museum setting foster experience and emotional involvement? We propose that when designing for these learning activities, the project group should take into account findings from both museum learning research and learning-oriented research.

The findings in this article have important consequences for the intervention design of the future project workshops. Studies within CHAT using a specific method of interventionist research design have provided substantial evidence on the importance of using artifacts, both physical and conceptual, as mediating objects to succeed in collaborative work (Ellis, 2008; Engeström, 2007; Engeström, Lompscher & Rückriem, 2005). When artifacts, such as learning concepts or digital representations, are constructed and interpreted between activity systems, a growing set of tensions emerges with regard to how to understand learning in science education, and how to organize for these activities across school and museum contexts. The identified tensions could be central sources for the design and development of learning activities across museums and schools. This article has demonstrated the importance of discussions that facilitate boundary crossing between the participants in the project group. How to actually construct such discussions, and how the multi-professional group engages in meaning-making activities, will be a focus in our future work in the MIRACLE project.

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