NORDIC JOURNAL OF DIGITAL LITERACY

COVER PAGE

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Title: Learning in Science Education across School and Science Museum – Design and Development Work in a Multiprofessional Group

Abstract: In this article, we discuss challenges in design work in a multidisciplinary group. We analyse video data gathered from a start-up workshop in a project, the aim of which is to design and develop learning models in science that will be used in and across schools and museum settings. A combination of digital technologies plays a vital role to bridge these institutional situations by offering a rich amount of representations. As an analytical framework, we use concepts from Culture Historical Activity Theory both to study the orientations of the various group members to learning in science education and to scrutinize contradictions between these orientations. We conclude by identifying three main orientations to learning in science education, namely, memorable experiences, embodiment, and conceptual understandings, and we discuss the implications that these have for the design of the overall learning trajectory. The findings in this article have important consequences for intervention design of the future workshops.

Keywords: multiprofessional groups, learning in science education, design and development work, Culture Historical Activity Theory, video data

Introduction

In schools, not only do students frequently have difficulty to make meaning of disciplinary issues in science, but their understanding tends to be fragmented (Arnseth, 2004, p. 39; de Jong, 2006; Krange, 2007; Roschelle, 1992). Teachers are likely to emphasis the performance of tasks rather than going into details and helping students to synthesize scientific concepts (Furberg & Ludvigsen, 2008; Krange & Ludvigsen, 2008). Internationally, students tend to choose disciplinary domains other than science when they reach educational levels where they can select (Vetleseter Bøe, Henriksen, Lyons, & Schreiner, in press). In science museums, museum guides report that students seem to be engaged during museum visits but the guides are concerned about the students' take-up afterward due to limited pre- and post-visit activities at school (Falk & Storksdieck, 2005).

Mixed Reality Interactions Across Contexts of Learning (MIRACLE) is a project that takes these challenges as its point of departure and intends to connect learning activities in science education at upper secondary schools to activities at the Norwegian Science and Technology Museum (NSTM). In this sense, the project aims to strengthen both the students' engagement with and conceptual understanding of scientific phenomena in and across different institutional settings. By conceptual understanding, we refer to Vygotsky's (1986) definition of scientific concepts: a concept is not scientific before it is considered in relation to, or as part of, a larger conceptual system. To strengthen both the students' engagement for and conceptual understanding of scientific phenomena in and across institutional settings, we will design and develop learning models, mediated by different social networking technologies, through which students will be introduced to such 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 MIRACLE project is constituted of a multiprofessional group of architects, learning scientists, interaction designers, computer scientists, animation specialists, and museum guides to design and develop these learning models. We consider this multiprofessionality as vital to be capable to combine challenges in the school with challenges in the museum to increase the students' interest for and conceptual understanding of science. Based on video data gathered from a start-up workshop that was arranged at the beginning of October 2010, we have derived three empirical research questions. First, we will analyze the different disciplinary orientations of the project members to consider what they take into account when talking about learning in science. Our first research question is:

- What characterizes the different orientations to learning in science education in the multiprofessional project group?

Secondly, we will distinguish possible contradictions in the search for a shared understanding of what the variations in meaning learning in science imply for the project members in this cross-institutional setting. We consider these variations as productive for the design and development of learning models in the sense that these might bring forward the best from each institutional setting. Our second research question is:

- What types of contradictions can be identified in the multiprofessional project group?

Moreover, in a more analytically motivated manner, we would also like to identify how these orientations and expected contradictions can be dealt with in further work with design and development of the learning models. We are planning for an educational trajectory during which students will be exposed to some issues in science such 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:

- How do the different orientations to learning in science and the contradictions between the multiprofessional members in the project group fit in with the planned educational trajectory crossing of the school and the science museum?

The data are gathered from presentations given by three different project members representing various disciplinary and institutional settings, and their separate statements will be contrasted and analyzed. As a theoretical basis, we will use Cultural Historical Activity Theory (CHAT). This kind of theoretical approach gives an entrance to an analysis of how the multiprofessional members in the MIRACLE project can be considered as institutional and disciplinary stakeholders. Within the CHAT literature, these stakeholders are regarded as representatives of social practices or so-called activity systems that are historically developed. Further, the identification of contradictions is the very purpose of this kind of analysis. The contradictions are thought of as natural features in all kinds of activity systems and judged as positive in the sense that these hold a potential for organizational improvements. In this sense, CHAT will give us a lens to understand and explore what is going on when members from different activity systems design and develop models for learning in science, and which cross the institutional borders between the science museum and the school.

Following this introduction, we will give a brief outline of relevant theoretical concepts gathered from the CHAT literature. This will be followed by an account of the methods that we used. Further, we will give an empirical analysis of some aspects collected from the start-up workshop. We will use the findings as a starting place from which to single out supportive strategies for the students' engagement in and conceptual understandings of science, and to link the activities at school more tightly with the students' engagement in the science museum setting.

CHAT: Multiple Orientations and Contradictions between Activity Systems

CHAT offers a framework for analyzing structures and dynamics in activity systems, and how they change (Engeström, 1987, 1999). CHAT was initiated by Vygotsky (1978). Instead of the Cartesian split between the individual and societal structures, Vygotsky developed a model in which cultural tools were seen as acting as mediators between the subject and the object. His thinking was further developed by Leontiev (1978, 1981), who focused on the concept of activity. 'Activity' is our unit of analysis and the focus is on complex interrelations between the individual subject and his or her community (Engeström, 2001). The basic assumption here is that human behavior and actions are related to a shared social purpose conceptualized as the *object* of activity. With the notion of object, CHAT not only seeks to understand what people are doing, but also why they are doing it. Individual actions are part of an historical and collective activity that is mediated by tools, rules, and norms and division of labor. According to this view, an individual's construction of an object is facilitated and constrained by historically accumulated constructions of the object (Foot, 2002).

Activity-theoretical studies have been concerned to capture the diversity of orientations among participants of an activity system or among multiple activity systems. Engeström (1987) suggests the use of the concepts of Bakhtin (Bakhtin, 1986; Holmquist, 2002; Holquist, 2002) for the analysis of multiple object orientations. In this article, we use voices as an analytic concept to elucidate the object orientations of the activity systems. Following R. Engeström (1995), voices are understood as communicative actions. According to Bakhtin, a voice is "a speaking subject's perspective, conceptual horizon, intention and world view" (Wertsch, 1991, p. 51). However, these actions are always mediated by words, which connect individual utterances to what Bakhtin calls social language. The voices are shaped by social languages, while being individually instantiated by the speakers. Within an activity theoretical

framework, this means that participants' communicative actions or voices are mediated by the activity systems of which they are a part (Engeström, 1995).

In today's complex character of the 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). The criteria of expert knowledge and skills are different in various activity systems. The boundaries between activity systems comprise established distinctions between activity systems and are created and agreed on by the participants over a long period of time (Kerosuo, 2006). Professionals face the challenge of crossing the boundaries between contexts, which means to enter "into a territory in which we are unfamiliar and, to one significant extent therefore, unqualified" (Suchman, 1994, p. 25). For multiprofessional teams, such as the MIRACLE project group, this implies that to succeed in their collaborative work effort, they need to negotiate different orientations of an object to achieve a potentially shared or jointly constructed object. In CHAT, this collective formation of new mediating concepts is designated as boundary crossing (Engeström, 2001; Engeström, Engeström, & Kärkkäinen, 1995). Analyzing the project group in terms of interacting activity systems means understanding the negotiation of multiple object orientations.

It is important for our case that the voices of the participants in the project group are facilitated and constrained by the history of their activity system; that is, how tasks have been solved earlier and how tools and digital representations have been understood and used. One of the main challenges with bringing together different activity systems is that their participants often understand and make sense of tools, such as technological representations, and scientific concepts, in different ways because there are different objects motivating the different activity systems. It is reasonable to believe that the multiprofessional project group will conceptualize and enact the object in diverse ways.

This leads to the second aim, which is to identify contradictions in the search for a shared understanding of the object: learning in science. *Contradictions* manifest themselves as problems, ruptures, breakdowns, or clashes (Kuuti, 1996) and are sources for change and development. Disturbances caused by different orientations to learning, such as those between museum guides and learning researchers, do not therefore only cause ruptures, but also open spaces of opportunity where these differences can be productively handled. The analysis of

contradictions holds the potential of understanding how the multiprofessional project group develops.

This article is the first in a series focusing on the design process. At this stage, the concern will be to analyse the different object orientations at play and identify some initial contradictions in the design process. 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 the start-up workshop arranged at the beginning of October 2010. This was a two-day session. The first day took place at the Norwegian Science and Technology Museum and the second day at the EngageLab at InterMedia, University of Oslo. An important part of the workshop was to get to know each other and to identify what each of the different participants could contribute. 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 models were introduced, tried out, and discussed. Other main activities were group work and brainstorming. All participants were asked to write post-it notes; these were then stuck on wall posters and each participant presented his or her ideas. The aim was to open up different possibilities and arguments for how to design and develop the learning models in and across the two institutional settings and across different technological solutions. The empirical focus in the following will therefore be to clarify the voices at play and identify contradictions between various activity systems. This article is seen as a first step in the joint search for a common object, and is important to be able to understand the coming negotiations.

In the following analysis, two types of data are used: documents and plenum presentations. First, it is *documents* that aim to give a picture of the historical activity each project member brings to the project. These documents are the project proposal and the consortium contract, which describe the different project members, their historical background, and competences. In addition, these kinds of background data also include *meetings* the university members of the project group have had with other project members. We refer to the relevant documents and meetings when these data are used in the analysis.

The second kind of data is the project members' *plenum presentations* at the start-up workshop. These presentations were video recorded. In total the workshop count ten hours of video recordings. We have selected three citations and we will argue that these illustrate the orientations of the activity systems participating in the project and the contradictions between these that were demonstrated by their views on learning in science. More specifically, these members consist of an architect from the architecture firm CoDesign, a museum guide from the Norwegian Science and Technology Museum, and two learning researchers from InterMedia, University of Oslo.[1] The first and the second kind of data have helped us draw a picture of the multiprofessional nature of the project group and how its members represent different activity systems when they argue about how to design and develop learning models in upper-secondary science.

That we as researchers, or in this case two of our colleagues, are participants in the group we are studying is an issue we need to be aware of. Our own voice should not be biased compared to the other multiprofessional voices that are presented. Practically, this means that we are *not* looking for some kind of normative idea about the right meanings of how to design and develop learning models in science but rather to identify the different orientations, how these are balanced, and can be taken into consideration when planning the educational trajectory crossing the school and the science museum. We will also use our socio-cultural research community to qualify this objectification of our analysis to make sure that we deal with the different voices equally.

Together, the two types of data give us three activity systems to study: the architecture firm CoDesign, the Norwegian Science and Technology Museum, and the University of Oslo. Storm Studios and the EngageLab at InterMedia are not present in the data partly because neither produced material that was found to be relevant during their plenum presentations and partly because this article does not discuss different choices for technology, which is the main activity of the Labs, at least.

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[1] The representatives from the researchers are two learning scientists and a computer scientist. These researchers work in the same department and understand the object, learning in science education, rather similarly. For the purpose of this article, they are considered to be part of the same activity system.

Different orientations about learning in science education and types of contradictions

The empirical analysis aims to examine the different object orientations of learning in science education and distinguish contradictions between these orientations. We explore the history of the MIRACLE project and identify how the different stakeholders, as representatives of different activity systems, orient towards the object of learning in science education.

The complex nature of MIRACLE requires collaborative teamwork. It was decided to organize the work in the design process with a multiprofessional project group to enhance the exchange of information and ideas across boundaries. The project group comprises members of professions with very different training, ideology, and status, and who is part of the project because of their specific knowledge expertise. To succeed in the aim of designing learning models that combine learning in schools with museum activities, the project group has to possess a mechanism that enables all participants to contribute and share information, ideas, and subject-specific knowledge (Engeström, 2008). CHAT studies within various organizations and professions have shown that exchange of knowledge and information between activity systems is necessary, but challenging (Engeström, 2008; Engeström, et al., 1995). The purpose of this section is to clarify the different object orientations to learning in science education and how these are potentially contradictory.

The Museum as Activity System

The museum has a long experience with preparing and presenting examples of breakthroughs in science and technological, from both a historical and contemporary perspective, and which is visible both in their permanent and temporary exhibitions. "Climate X" is an example of a temporary exhibition during which several spectacular manifestations, such as ice blocks and water pools, were used indoors to show the effects of climate change. The museum has a good relation to the educational sector, and about 50% of the schools in Oslo visit the museum every year (consortium contract). In his presentation, the museum guide described the plans for their upcoming exhibition "Power for Norway," which is connected to MIRACLE. The museum guide explained that for a museum, it is not enough to exhibit fancy technology or other physical artifacts; rather, they should communicate a message mediated by physical artifacts. In his presentation, the museum guide emphasized the experience an exhibition gives:

> 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 guide).

The statement of the museum guide voices the museum experience. His primacy is not on learning the principles of science, such as the greenhouse effect, rather, he emphasizes that a memorable experience may later on result in knowledge.

The Architecture Firm as Activity System

Another central representative in MIRACLE is the architectural office CoDesign. This office, which specializes in museum exhibitions, has collaborated with the museum on their previous exhibition Climate X, and they will also collaborate on the upcoming "Power for Norway" (consortium contract). As the museum guide explained in his presentation, the museum has handed over the themes they have chosen for the exhibition, which the exhibition architect later used for generating ideas for designing the exhibition. The architect showed in this presentation how they designed Climate X, which artifacts they used, and why. Among other things, they brought an ice block from Svalbard, which was used to present the research understanding of the climate change, and the fact that the ice block was melting was seen as a reminder of what the climate change is doing to us. The architect emphasized that in their work, they try to design for other ways of interacting in museums than how interaction in museums traditionally has been represented. That means that museum visitors should not just push a button, but the exhibition should be designed in such a way that the visitors become emotionally engaged with the presented subject:

> 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 architect).

The statement of the architect voices exhibition experience with a focus on embodiment. His interest is to design for exhibition experiences in which the visitors interact with physical artifacts in new and engaging ways. A good exhibition will give the visitors a personal experience during which they are emotionally engaged.

University of Oslo as Activity System

The last representatives in the project group we focus on in this first section are the learning researchers. 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. Each of the two learning researchers giving presentations at the workshop was 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 pupils have difficulties with making sense of the principles of science, which means to have a conceptual understanding of the issue. Both of the learning researchers referred to the exhibition architect in their presentations with a focus on embodiment, but stressed that it is not certain that the engagement with artifacts will develop as anticipated in the design. A simulator in the present energy exhibition at the museum was mentioned as an example, and the learning researcher argued that when students approach the simulator, their focus would probably be on winning the task, with the result that the science in the experience disappears. The other learning researcher referred to the exhibition architect's argument to clarify their perspective on learning:

> I believe that to be right [the door opener 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 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 CO2 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 (learning researcher).

In his statement, the learning researcher confirms that it is important to find strategies to motivate and engage the students. In other words, he acknowledges the others focus on experience and embodiment. However, he stresses that to demonstrate learning the students have to able to explain the scientific principles behind what is experienced. Experience and embodiment can therefore be important motivational triggers, but cannot be considered as learning. The statement of the learning researcher first and foremost represents a learning-centred approach, where the orientation to learning is conceptual understanding.

Summing up the analysis – identifying patterns of orientations about learning in science and contradictions between these

The analysis gives an historical account of the discipline's specific knowledge that the three activity systems bring into the MIRACLE project. The project group can be seen as an interaction between multiple activity systems that do not yet have an established practice, but reflects the attitudes, norms, and roles of the present activity systems. This means that the actions and interactions of each of the project group's members are regulated by the activity system each represents. We argue that the three activity systems are concerned with the same object, learning in science education. According to how the representatives voice their presentations however, we found that the activity systems have different orientations to the object. These three orientations are identified as memorable experiences, embodiment, and conceptual understandings. As a museum, they are interested in making exhibitions that provide memorable exhibition experiences of a high quality. Although they are concerned about the students' take-up from museum visits, their primary interest is to make exhibitions that are so good that visitors get an unforgettable experience. For museums, therefore, their orientation to learning in science can be seen as *memorable experiences*.

The orientation of the architectural firm is much the same as that of the museum, but there are nuances in their orientations that reflect their different expertise. As exhibition architects, they are also concerned with making the experience memorable. However, what that means is more specific. The exhibition architects want that museum visitors should be emotionally engaged during a museum visit. On this background, we will argue that their orientation to learning in science is that of *embodiment*.

The analysis shows, not surprisingly, that the learning researchers have a different orientation to learning in science. As educationalists their concern is that students in science education should reflect on the principles of science. They confirm that experiences and embodiment can be central motivator for learning, but it requires some sort of uptake from the student. In other words, experience and embodiment are not understood as learning. Their orientation to learning in science can therefore be seen as *conceptual understanding*.

What is interesting to look at, from the perspective of further negotiations of the object, is how they voice their arguments for their interest into the project in their presentations.

In her study of a Finnish health care organization, Kerosuo (2003) analysed how boundaries identified evolved during discussion. She categorized boundary expressions as speech aiming

to maintain, question, and transform the prevailing boundary. In our analysis we can identify a difference in the argumentation for the object, on the one hand, of the museum guide and the architect, and the learning researchers on the other. The first two voice their arguments by making statements. Kerosuo (2003) sees statements as speech aiming to maintain the prevailing boundaries. The focus of the museum guide and architect is on presenting their interests, without questioning their view or seeing it in relation to others. Their position and their interests in the project are clear, but how they relate to the overall object of the project is more tacitly assumed. The learning researchers, on the other hand, have a different focus, wherein they explicitly address the collective object of the project. Instead of making statements, their voices aim to transform the prevailing boundaries between the activity systems by confirming and supporting the others' voices, and at the same time elaborate upon them. This focus is achieved by temporarily overstepping the scripted boundaries.

To conclude, the previous analysis has clarified the different orientations to learning in science, and how each participant voices his or her arguments. In many ways, this analysis sharpened the differences between various object orientations. One reason for this may be because the collaboration between the activity systems in this setting was based on presentations from the representatives on their interests into the MIRACLE project and did therefore not result in any discussion of concept formation. In a study of boundary crossing in three cases, Engeström, Engeström and Kärkkäinen (1995), found that it is difficult to cross boundaries by the means of meetings alone, without identifying concrete problems to solve. We will come back to this point in the conclusion.

Discussion and concluding remarks

The aim of this study has been to better understand the design work in a multiprofessional group during a start-up workshop in the MIRACLE project. The overall project aim is to design and develop learning models in science that will be used across schools and museum settings, and it is therefore vital to identify the members' different orientations to learning in science, and how these contradict, to get the best out of each partner in the following cooperations. We will in the following discuss the different orientations to learning in science and the resulting contradictions between the multiprofessional members in the project group. Then we will discuss our third, more analytically motivated research question: How does this fit in with the planned educational trajectory crossing the school and the science museum?

The first aspect of the discussion is linked to the question of what characterizes the different object orientations among the members in the multiprofessional project group. Overall we can say that the members representing different activity systems are interested in participating in the MIRACLE project because all consider it necessary to improve the students' learning in science, whether this learning takes place at school or at the museum. Moreover, the members also agree that this can be done by connecting the museum experience to pre- and post-activities at school. However, as the analysis of the documents and the plenum presentations of the start-up workshop have shown, a contradiction exists in how the different members conceptualize learning in science. These orientations, when considered as a whole, give a picture of the main concern of the members and the activity systems they represent. As we remember, three different orientations were identified: while the museum guide saw learning as *experience*, the exhibition architect considered it as *embodiment*, and finally, the learning researchers understood it as *conceptual understanding*. We will argue that the systems are all oriented to the same object: learning in science education.

Kaptelinin and Nardi (2006) argue that in collaborative work, it is expected that the various members have different motives related to the same object. We want to take our above-mentioned finding about different orientations one step further by systematizing these according to the various members' motives for how they relate to learning in science as an object and discuss the implications of such a view. Looking at the three orientations, it becomes clear that these sort into two main motives: the idea of a spectacular science-museum experience and the plan for supporting students' conceptual understandings of scientific phenomena.

The museum guide and exhibition architect share the first motive. This is more generally based on a critique of science-museum exhibitions as trivial and not very stimulating. By designing more complex interactions between the visitor and the physical artifacts, these two members aim to develop a memorable museum experience. The exhibition architect takes this one step further by concretizing this to include some kind of embodiment. The learning researcher's motive is of another kind in that it leans on previous research emphasizing students' problems to scientific concepts (Vygotsky, 1986) when participating in science education (see i.e.: Krange, 2008). Although these motives differ, we will argue that they must be considered as interlinked and central to the MIRACLE project as collaborative activity. We can say that in particular, the museum guide, but also the exhibition architect, are concerned with the students' take-up from museum visits and with how the museum activities

are presented in pre-visit activities and elaborated on in post-visit activities. These two members foreground the importance of the students' experience and embodiment of the planned museum exhibition "Power for Norway". On the other hand, the learning researchers foreground the problem of making scientific concepts but are also concerned with exhibition experiences like embodiment. However, this latter interest is placed in the background.

We are now ready to turn to our last research question and ask how the different motives and contradictions between these members fit in with the planned educational trajectory with pre-visit activity at school, followed up by different activities during museum visits, and supplemented with post-visit activities back at school. Collaborative work between experts from different professions is vital to the combination of challenges in school with challenges in the museum. Multiprofessional 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, embodiment, and conceptual understanding in increasing the students' interest in and engagement with, and conceptual understanding of, science—but such notions exist on the visionary level and represent abstract goals. Despite their accord on the importance of the three, the members in question have different orientations on how to integrate experience, embodiment, and conceptual understanding across schools and museums. When designing for learning, should the experience or the scientific reasoning be the focus? Should there be some part of embodiment 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 engagement? Should it be localized in school, in the museum, or in both places? Furthermore, when designing for these learning models, we should take findings in museum- and learning-oriented research into account.

Museum studies have documented 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, it is a danger of making the museum visits too 'school-like'. Other studies haves found that the structure of museum experience influences what students remember and understand (Anderson & Shimizu, 2007; Hubard, 2006; Pierroux, Krange, & Sem, submitted). Learning-oriented studies have indicated

that students have difficulties understanding relevant meanings from visual and spatial representations of science (Schnotz & Lowe, 2008). The ability to interpret a physical or digital representation is dependent on prior knowledge, because otherwise, students do not know what to look for. It has also been demonstrated that more complex, realistic, and dynamic representations do not necessarily make reasoning with representations easier (Krange, 2007). In future workshops, when the project members have to make decisions, it is important to find ways to combine these different orientations.

The findings in this article have important consequences for intervention design of the future 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 a mediating object to succeed in collaborative work (Ellis, 2008; Engeström, 2007; Engeström, Lompscher, & Rückriem, 2005). When artifacts, as learning concepts or digital representations, are constructed and interpreted between activity systems, a growing set of contradictions emerge in how to understand learning in science education and how to organize for these activities across school and museum contexts. The identified contradictions could be central sources for the design and development of learning models across museums and schools.

This article has demonstrated the importance of discussions that facilitate boundary crossing between the participants in the design and development group. How to actually construct such discussions and how the multiprofessional group engages in meaning-making activities will be the focus in an upcoming article.

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