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Designing for Play-Based Learning of Scientific Concepts: Digital Tools for Bridging School and Science Museum Contexts

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Abstract

Playing and schooling are usually considered as separate activities. In this article, we argue that these activities can be reconciled in order to design learning experiences that are more exploratory and engaging. Taking a socio-cultural perspective on playing and learning, we provide examples that bridge museum experiences with school-based activities in order to facilitate students' learning of scientific concepts. In the project discussed, different technological devices are used as play-based tools for connecting science learning in the two institutional settings. In this article we discuss the implications of research in different fields of inquiry for designing play-based learning activities. We illustrate this complexity by analyzing how a multi-disciplinary professional group negotiated their understandings of how playing and learning could be combined, and we give a brief presentation of how the actual learning trajectory was operationalized into design.

Keywords: interaction design, socio-cultural perspective, science education, play-based learning, museum learning

Introduction

This article reports on an emerging learning design project called Mixed Reality Interactions across Contexts of Learning (MIRACLE), which has the aim of integrating play-based inquiry learning into science education at upper secondary schools. These designs for learning experiences are exploratory and engaging, and at the same time oriented towards the learning of scientific concepts. The project is inspired by design-based research (Brown 1992). This implies that we design for educational interventions and later perform detailed studies of how these interventions work. Our motivation is to overcome some of the major difficulties students experience in science education. Namely, within school settings, it is difficult to create situations where students can easily practice science rather than simply rehearse skills or recall factual content (Kangas 2010). Further, the meanings of scientific concepts are often experienced by students as highly abstract and difficult to grasp (Säljö and Bergqvist 1997).

Museums and science centers are increasingly becoming important settings for the learning of science. Science educators are strongly supporting out-of-school learning experiences as important and effective additions to school-based science learning (Rennie 2007). Play-based inquiry environments constitute settings where children and youth can explore problems and engage with objects to make meaning of their properties and functions as part of activities that are motivating and engaging. In the MIRACLE project, iPod apps, simulations, interactive whiteboards, social media—or what we have termed a "Science Hub"—as well as motion-sensing input devices, are used as play-based tools for fostering students' learning of scientific concepts related to energy. With the term "learning of concepts," we refer to students' ability to make meaning of scientific concepts and to construct relationships between them, forming larger conceptual systems.

Some researchers emphasize that future studies in science education should focus on blending informal and formal learning experiences in order to enhance the learning of science (Hofstein and Rosenfeld 1996). We argue that schools and museums constitute historically developed institutional practices with different norms, rules, and divisions of labor. This means that what counts as knowledge and legitimate participation differs in these two practices. Instead of blending these experiences, we propose a design that, through the use of various digital artifacts, makes a coherent learning trajectory available for students across schools and museums. Against this background, we explore two questions:

1. What characterizes play-based and inquiry-oriented approaches to science learning at schools and in museums, and how can this inform future designs?
2. How do the institutional contexts of schools and science museums mediate the design of play-based learning activities that cross these contexts?

Play and Learning from a Socio-Cultural Perspective

Our design research is anchored in a socio-cultural interpretation of learning (Säljö 1999; Vygotsky 1978; Wertsch 1991), which implies that we regard people as being fundamentally social beings; hence social interaction is our field of analysis. More specifically, this means that language-based interplay and interaction with artifacts have a predominant role in the design of an educational program for students and teachers.

From a socio-cultural perspective, play is a specific form of activity characterized by a certain orientation to objects and environments. The everyday ordering of activities is somehow set aside, and children and youth can more freely experiment with and negotiate meanings, roles, and rules.

> *Early in their lives, children begin a type of play in which the everyday meaning of objects is suspended, and new meaning is assigned to objects, others, and self. Behind the couch becomes the bad guy hideout, under the table becomes the jail. One's playmate becomes the sheriff; oneself the outlaw. Or perhaps a certain set of everyday meanings is retained and highlighted, and other features drop away* (Holland and Lachiotte 2007, 112).

At an early stage in development, children play with the meaning of objects.

> *A symbol is a sign, but the stick does not function as the sign of a horse for the child, who retains the properties of things but changes their meaning. Their meaning in play becomes the central point and objects are moved from a dominant to a subordinate position* (Vygotsky 1978, 98).

Later in development, children's play becomes more abstract and oriented to rules. According to Vygotsky (1978), play is about object-meaning and action-meaning relations, and the meanings of objects and actions emerge as part of the activity of playing. Whether something is play is not given by the concrete circumstances, but is a consequence of the child's meaning making, which develops in social interaction with others. For Vygotsky then, children playing games is a crucial precursor to the development of more abstract thought, since they gradually become more attuned to the meanings of things and actions. They become able to negotiate meaning in regard to specific rules and norms while structuring activities. Thus, the organization of the activity of playing gives meaning to the actions and objects; for instance, the goal of winning a race becomes the object driving the activity. Play serves as a precursor to participation in institutional life since children and youth in play shift to a conceptual world beyond the everyday and submit to the premises of the play activity. According to Vygotsky (1978, 97):

> *In play thought is separated from objects and action arises from ideas rather than things: a piece of wood begins to be a doll and a stick becomes a horse. Action according to rules begins to be determined by ideas and not by objects themselves.*

In play, the consequences of actions and learning only have relevance within the confines of the game. Since they are free from the immediate circumstances of a given task, children and youth can play with meanings and rules and easily recast the goals of the activity (Rogoff 1990). For the sake of our argument, introducing more theoretical conceptual materials while retaining an orientation that emphasizes play and experimentation with conceptual relations represents a crucial challenge. What is interesting in terms of retaining playfulness in school-based learning of science concepts is that in play, action is subordinated to meaning. In contrast, in science education, action dominates meaning in the sense that making meaning of concepts is replaced by the immediate constraints of solving task assignments.

Design efforts inspired by socio-cultural ideas often argue for a process of guided inquiry (Rieber, Tzeng and Tribble 2004). Studies of students' science-focused collaborative activities show that students need guidance and support in order to recognize the relevance of problems they encounter (Säljö and Bergqvist 1997) and to understand why, for example, they make mistakes and what these mistakes mean (Donald 1991; Furberg and Arnseth 2009; Krange and Ludvigsen 2008). According to Vygotsky (1978) and his theory on zone of proximal development, it is impossible for a child to build a jigsaw puzzle without guidance from a more competent person who can contribute to structuring the process. This does not imply that the solution or the puzzle-solving procedure is presented in advance. The child should take an active part in building the puzzle. The critical question is when and to what degree the adult should show or model what the child should do rather than to call attention to or provide relevant cues that will lead the child in the right direction.

Our design seeks to tie students' science learning activities to real-world issues and first-hand experiences with scientific objects to stimulate students' active exploration of meaning relations (Roth and Barton 2004). Still, research also demonstrates that such efforts often conflict with the institutional demands of schooling, in that the activities are transformed into tasks to be solved (Arnseth and Ludvigsen 2006). Thus, science learning in schools tends to focus on procedural problem solving (Krange and Ludvigsen 2008). Students often have problems with understanding concepts and linking them to larger conceptual systems (Arnseth 2004; Krange and Ludvigsen 2008; Kumpulainen and Wray 2002; Roschelle 1992). It is, therefore, a challenge to design activities that help students not to just deal with the concepts for the purpose of solving the task, but also to understand what these mean in a scientific context.

In a socio-cultural perspective, artifacts mediate all activities. The mediating aspect reflects the elements of knowledge connected to the artifacts, which can enable students to perform more advanced activities than what would be possible without these tools (Säljö 1999; Wertsch 1991). An illustration of this is the built-in mathematical principles of a calculator, which, for example, enables students to easily extract the square root of any figure without necessarily understanding the underlying, basic mathematical rules for this arithmetic operation. Learning scientific concepts needs to be followed up by the design of artifacts and made relevant *in situ*, guided by a teacher or a more competent peer. Artifacts may be both real-life and virtual, and due to this type of alteration, the students' activities are mediated in different ways. The understanding of artifacts, as a simulation for example, is not trivial. Where to focus and what to interpret is not a given and often relies on extensive experience and knowledge about the scientific phenomenon being represented. The difficult thing for students is that this knowledge has to be developed in tandem with the interpretation of the models (Goodwin 1997; Krange 2007; Ivarsson, Scoultz and Säljö 2002).

Play-Based Learning in Museums

There is a substantial body of research on science learning in museums. Most of the research has focused on the multiple factors influencing visitors' or students' learning from museums (Anderson, Lucas and Ginns 2003; Falk and Dierking 2000; Hofstein and Rosenfeld 1996). Even though there is plenty of research on the role of motivation, engagement, experiences, and emotions in the museum literature (Falk and Dierking 2000; Csikszentmihályi and Hermanson 1995), there is little research that explicitly refers to play. The research literature that is concerned with playing often focuses on its linkage to learning. In her review of learning science outside of school, Rennie (2007) refers to a study by Diamond that reviewed the relationship between playing and learning and concluded that museum experiences can encourage playing, from which learning occurs. Similarly, Rennie and McClafferty (2002) examined the relationship between playing and learning with young children in a science center by focusing on the way they used exhibits as objects for exploration or as tools for games. Hawkins (1965) found that children need time to explore and interact with new or unfamiliar equipment before they begin serious work, and the same seems to be true in science centers (Rennie and McClafferty 1995). This also seems to be the case with older children, and even adults. In a study of how university students use interactive exhibits in college physics teaching, it was found that the students needed time to play with and explore the exhibits before they began to understand them (Semper, Diamond and St. John 1982). It seems to be quite a robust finding that some forms of play are essential for learning (Heath, vom Lehn and Osborne 2005; Semper, Diamond and St. John 1982; Rennie and McClafferty 1995).

These findings are confirmed in research on museum learning in general where museums are found to have a short-term effect on motivation and interest in science learning (Falk and Stoksdieck 2005). There are contradictory findings on whether these visits also have an impact on the learning of scientific concepts (Jarvis and Pell 2005; Zoldosova and Prokop 2006; Fernández-Manzanal et al. 1999; Knox, Moynihan and Markowitz 2003). While the majority of this research literature has been concerned with individual or group learning within the limited physical scope and time scale of a museum visit, what happens before and after the museum visit has rarely been taken into account (Falk et al. 2004). Some longitudinal studies have shown that even though visits do not result in immediate learning, the potential for learning is available. In many cases, visitors report outcomes some time after the visit that is different from those they report at the time of the visit (Falk and Dierking 2000).

From museum research, we know that museums and schools often fail to collaborate on how museums could be integrated into planned learning activities. Teachers rarely prepare for museum visits (Griffin 2004), which means that the relation to school activities and the curriculum is weak. Museum visits tend to be seen as a day off for students and teachers, or as an isolated activity, due to limited pre- and post-visit activities at school (Falk and Stoksdieck 2005).

The research literature points to four main factors for preparing students for museum visits. First, it is important to orient the students to the physical settings of the museum (Kubota and Olstad 1991; Anderson et al. 2000; Jarvis and Pell 2005). Without introduction to the physical organization of the environment, students have difficulties with making choices about what to do and are overwhelmed by the wealth of activities available. Secondly, field trips should be closely integrated with the curriculum (Orion and Hofstein 1994). Third, students should be introduced to skills and knowledge about the topic before the visit (Jarvis and Pell 2005). Finally, students should be "psychologically" prepared, meaning that they should know that the museum visit is a learning experience (Orion and Hofstein 1994; Jarvis and Pell 2005).

While several researchers have stressed the importance of pre-visit activities, the influence of post-visit activities in the classroom has not been extensively described in the literature. However, studies by Anderson and colleagues (2000; 2003) investigated how students construct knowledge about electricity by drawing on their experiences during a school visit to a science museum and subsequent follow-up activities in the classroom. Taking a constructivist perspective, they link students' prior knowledge, museum experiences, and post-visit activities to provide an account of the transformation of knowledge throughout the different phases. Based on students' concept maps and pre- and post-interviews, Anderson and colleagues suggest that students developed increasingly sophisticated understandings of scientific concepts.

Playful Inquiry Learning across Museums and Schools

Given the research on play-based learning and learning in science museums, it seems reasonable to argue that the use of various types of interactive technological games and toys, as well as museum visits, are important for creating interest and motivation for science learning. The challenge is that playful experiences do not seem to enhance students' level of abstraction. Rather, museum visits and play-based learning situations are important for creating interest, motivation, and relational thinking in science learning (Falk and Dierking 2000). However, to develop students' understanding of scientific concepts it is critical to provide varied kinds of teacher support and scaffolding structures (Säljö and Bergqvist 1997; Furberg and Arnseth 2009).

To trigger the students' disciplinary curiosity, the MIRACLE project uses a guided inquiry-oriented approach, in which the scientific issues are increasingly structured during the students' learning trajectory in pre-visit, museum visit, and in post-visit activities. Designing these learning activities is a complex process motivated by a socio-cultural perspective, prior research, and a set of workshops with different relevant stakeholders such as museum curators, exhibition designers, researchers, scientific programmers, teachers, and animation specialists. The learning models will be tested in a three-step procedure: The first iteration is a lab test (one year out in the project), the second iteration is a pre-test of a design experiment (one and a half years out in the project) and finally, the third iteration is the design experiment (two and a half years out in the project). All workshops and tests will be video-recorded. The two tests will feed back into the system design.

In order to provide some insight into how the design process develops, this paper provides an analytical example from one of our workshops involving some of the participants in the project. The example is from Workshop Five, nine months into the project. The workshop was attended by researchers, learning designers, museum staff, and exhibition designers. The workshop was held in English, and it is important to note that most of the participants are non-native speakers. The transcripts have, however, kept the original elocutions. After the analytic example, we will give a brief outline of the design of the learning trajectory before the first iteration.

Negotiating the Design of Playful Learning Activities: An Analytical Example

In previous studies of the design process, we found that the concept of energy was presented, understood, and talked about differently by the stakeholders. While the museum curators focused on designing activities that gave the students interactive experiences, the exhibition designers focused on emotional involvement, and the researchers emphasized the design of activities that developed students' understanding of scientific concepts (Jahreie and Krange 2011; Jornet and Jahreie 2011). In other words, in the early stages of the design process, playing and learning were seen as separate activities for the stakeholders. In Workshop Five, the notion of "space" evolved as a shared object in the interactions, which had consequences for how the stakeholders negotiated the design of playing and learning across schools and museums (Jornet and Jahreie 2011). This interactional turning point is the prerequisite for the excerpt below.

The excerpt is taken from a group session following a presentation from the research group and the architects—where possible, technological solutions and spatial designs were proposed. The team was divided into two groups for discussion. The aim was to discuss the proposed scenarios, and to come up with ideas on how to combine technology, the exhibits, and exhibition activities. The group we followed discussed the design of a heat pump exhibit, which is an important topic in the curriculum. In a sequence preceding this excerpt, one of the researchers was concerned about the complexity of the scientific concepts involved in the representation of the heat pump. In the excerpt, P is the exhibition designer; O, T, and C are researchers and learning designers; and J is a curator at the science museum. We have glossed over some of the details of the transcript to increase readability and to communicate the main points more clearly.

> (1) O (talking to P): I mean, talking about experiences, the connections between architectural designs, spatial design. Hmm, how do you create the sense of... curiosity, for instance? How do you create the sense that I have to (...) slowly, because it's something difficult to understand?

(2) P: (takes a moment to think) From a spatial point of view? [*They talk for a while about examples of architectural features, such as the doors in supermarkets.*]
(3) T: It's like the slow track on an album, that leads to a fast track, that leads to a slow track...
(4) P: Yeah, but that's drama! (...) how things are connected. "I do this, because what I did before is connected" (using someone's else's voice), because you start to individualize the experience. Which means that you have also the possibility to start writing stories. And this is always the question: should we let the visitor write the story? When someone is visiting the science center and looking upon it, should we tell them, "We don't say anything; you do whatever you want to do"? Or should we tell them: "This is the story. This is how we do it." Or is it something in between: "There are five different stories to be told here. You can pick up any one of them. But you have to pick a story." Or is it like(...) chapters? "You have to at least pick a chapter; at least, you have to expend this amount of energy into understand this." And this is...This is an intellectual question, really. I think it would be interesting to think of dramatizing, starting to tell stories in the science centers. Because I don't think that, ... I know that that's really exactly the opposite of the science center's religion. And I am not religious.... Telling stories in the science center is something that... you don't do. That's not the way you do it. It's the other way around.
[*J explains the difference between a museum and a science center. The science center is based on the Exploratorium set up, where the exhibition consists of different, often disconnected exhibits. The focus is therefore on installing good exhibits instead of the overall theme*].
(5) O: But, I am curious about this expectation thing in relation to the exhibition itself versus the educational program. Because I guess the educational program tries to conceptualize, or connect, or something. To create the story, I guess, basically out of the exhibits.
(6) J: But it's impossible to do education in the science center without an educational program, because of the noise. It's hopeless, so you can't really do that.
(7) O: But let's say we do it, as a proxy, we do it by the I-pod.
(8) J: Exactly. That's a possibility. You can create that story. "Go to certain exhibits, go there, do that," you know...
(9) P: But coming into answering your question about what architecture can do in this [*exemplifying with a dramaturgical analysis of the movie* Crash].
[*J takes up P's example, and explains a current exhibition, "Mind Gap." In this exhibition there are three rooms, with different, contrasting architectonic and iconic features.*]
(10) O: I think we have three spaces right now. We have the old science center, we have the new energy exhibition, and we have this kind of lab thing.
(11) J: Yeah.
(12) O: So maybe that's three stepping-stones in the trajectory...

> (13) P: This is what I am always arguing about, that one should start from the museum as one, and then start... Because then you can build the dramaturgical curve of the whole thing. Because then you can contrast spaces to each other.
> (14) J: But, give me a concrete question [*turns towards O*].
> (15) O: Educational program. Expectations. How do you create notions of curiosity, of engagement, in the space here, that we could try move to the classroom afterwards?
> (16) J: Competition. Collaboration, again. That's the way to work. You have expectations; you need to collaborate to get results...
> (17) O: I agree, I mean those two are good words. But what constitutes engagement...
> (18) C: How does the museum foster collaboration...
> [*J answers again referring to the educational program as the key component, structuring activity into competition, through open-ended questions.]*
> (19) O: Yes, ok! So we have competition between the... we have dyads or triads going around in the exhibition, I guess. And you suggest that these groups compete with each other, and we have to come up with something they need to achieve or...

Without going into the details of their talk, but instead focusing on topical development, it seems obvious that the central concern for the participants in the discussion is how they can design the exhibition in a manner that stimulates students' curiosity, interest, and motivation to pursue their meaning making of the difficult concepts involved. In other words, their concern is how to design for a connection between playing and learning in the exhibition. There are three elements to the spatial design that are worth noticing at this point: redesigning the museum exhibition on energy, incorporating the science center into the activities, and the possibility of creating a space where activities concerned with energy can be designed. The possibility of designing this third space was introduced in the workshop, and this became a partially shared object for the group (Jornet and Jahreie 2011). Having said that, and as we will demonstrate below, the different participants still had different views and perceptions on how a connection between playing and learning should be designed.

It is not particularly surprising that multiple voices came into play since the participants had different roles and interests in the project. This is also made visible in their orientations in the excerpt. P is primarily concerned with creating spatial designs that are interesting and engaging, and he particularly introduces the notion of drama and storytelling as important techniques for learning activities (line 4). The museum curator, who has a particular responsibility for the science center part of the museum, points to the notion of collaboration and competition as ways and strategies for engaging visitors and creating an educational trajectory (lines 16 and 19). In the museum, this is a common strategy employed in addition to guided tours, both in the museum's exhibition space and in the science center. The researchers are concerned with the overall learning trajectory (lines 1, 5, 15). They are also interested in designing for engagement, but see this as a precursor to more conceptual learning (Observations Workshop Five, June 23rd 2011).

Thus, both the exhibition designer and the researchers add something to the traditional way of doing things in the museum, which point to interesting possibilities for developing an overall trajectory. The notion of connecting spaces using storytelling techniques adds to the traditional way of experiencing museums as consisting of separated things and activities, where objects and artifacts are usually combined with some form of textual display. In these situations, it is not clear to students how installations are connected, for instance in regard to the broader theme of energy. It is also a common strategy for visitors to engage with installations without being oriented to the textual displays. Thus, they have a tendency to pull levers, press buttons, and so forth without inferring any meaning in regard to their actions. As mentioned in the theory section, they can play with the objects and constitute their pulling of levers as meaningful in regard to the objects, if it is part of a competition and a way to win (Vygotsky 1978; Holland and Lachiotte 2007). However, when they push buttons and see things happening, they are not necessarily able to explain why or how it happens (Heath, vom Lehn and Osborne 2005). Both the exhibition designer's and the curator's way of engaging students are, of course, interesting and legitimate and based on their previous experiences. Visitors are probably engaged both when they are participating in a story and when they engage in competitions. The researchers' concern, though, is that the students will pursue procedurally oriented activities, where the focus is on solving the task or winning the competition, which are separated from the conceptual issues (Roschelle 1992; Kumpulainen and Wray 2002; Krange and Ludvigsen 2008). This does not mean that we do not want to design for these kinds of activities. Rather, we want to see engagement and play as a precursor to more conceptual meaning making. The project group took into account these competing views, and came up with a design, described above. This is the design of the learning trajectory as it looks before the first iteration.

Designing a Learning Trajectory across Schools and Museums

The design of the learning trajectory is grounded in a socio-cultural understanding of learning, as well as previous research on science learning in schools, museum learning, and technology-enhanced learning. The expertise of the different stakeholders and the ideas generated in the workshops are also central for the design. The disciplinary issue of the project is energy of the future. The first iteration has a special focus on heat pumps as a means for explaining a range of scientific issues and relations, such as energy transportation, temperature, boiling point, evaporation, and pressure. We have introduced tasks and activities that reflect our intentions to mediate these scientific concepts in an inquiry-oriented, collaborative, and playful way. We describe these activities briefly below. In particular, we address how the activities are mediated and how the tasks are inscribed by artifacts on different levels: 1) by the physical spaces—namely, the classroom and the museum exhibition, 2) by the digital and physical artifacts, and 3) by the flow of digital learning resources, student generated material, and other triggers and scaffolds that shape and sustain the play-based learning activities across contexts.

Preparations at School

The learning design starts with the teacher introducing energy as a problem space by looking at the consequences of use, challenges regarding future consumption, and some initial explanations about central concepts such as pressure, heat, condensation, and evaporation, in a plenary session in the classroom. Students are then organized into groups of three where they will do three different experiments with an injection, a bike pump, and a spray can. These tools focus the students' attention on the relation between heat and pressure, and will hopefully help to give the students a preliminary understanding of how heat pumps work.

Further, the teacher will introduce the Science Hub as a tool for the students. "Science Hub" is a portal that connects experiences in the museum context to the learning activities in the classroom. The infrastructure support computational integration in hybrid environments, i.e. featuring both unfolding phenomena in physical spaces and simulations in digital environments. The Science Hub works as the main digital resource throughout the learning trajectory. This tool works not only as a personalized interface, but also as an interface where students can access their group's work and as a place where the teacher can assess the students' work throughout the trajectory. Through SciHub, collective learning activities, curricula themes and students progress are made available on multiple devices, such as tablets, webpages, and interactive surfaces. The Science Hub will have an interface designed both for computers and for iPods. The students will make a profile for use on the Science Hub. Thereafter, the students will be asked to use iPods[1] to make a short video of their first interpretations of heat and pressure and then send these to the Science Hub for later elaborations. The teacher sums up the experiment session and makes the first steps towards considering the three experiments in relation to each other.

The next step in the classroom is for the teacher to give an introduction to the museum visit. The teacher will present a layout of the museum, where the exhibition is located, and what exhibits the students should pay particular attention to (Kubota and Olstad 1991). Further, the teacher will give detailed instructions of what kind of activities are expected of the students (Orion and Hofstein 1994; Jarvis and Pell 2005). The students will be asked to interact with an interactive wall (supported by Kinnect technology) representing the heat pump. They will be asked to make a short video reporting on their interactions in combination with their preliminary interpretations of how a heat pump works. Finally, the teacher gives a short introduction of what they are going to do when they come back to school—working with digital simulations and playful tangibles.

Museum Visit

The museum visit starts with a museum educator introducing the energy exhibition. Various energy sources are explained and contextualized in terms of societal importance, energy politics, and the future role of various energy sources. The students will then go to the exhibits where they will be introduced to tasks through the Science Hub interface on their iPods. The main exhibit in the first iteration is an

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[1] The MIRACLE project provide a class set of iPods.

interactive wall that uses Kinnect technology. We have designed a digital game that makes it possible for the students to play with different elements of the heat pump represented on the interactive wall. In the game, the students can see themselves represented as avatars. The students have to warm up a house, where people are freezing inside. With their body movements, the students will control avatars that appear filled with liquid, representing the fluids inside the heat pump cycle. It is not the details of, for example, condensation or evaporation that the students are meant to understand, but rather to get a picture of how these different physical elements are combined.

The students will document their interactions with the Kinnect wall and their interpretations of the heat pump by making a short video. Again they will use iPods to make the necessary recordings and send them to the Science Hub. The teacher and the museum educators will be available for questions during the exhibition. The implications of the different elements will later be picked up and elaborated on in the post-visit setting. Back at school the students will be asked to further develop their scientific concepts using a heat pump simulation.

Post-Visit Activities
Back at school, the teacher follows up the initial videos from the pre-visit activity with low-tech tools and the videos from the Kinnect wall. He focuses on the more general physical principles, what the basic concepts imply, and how these relate to larger conceptual systems. From the students' videos, the teacher gets information about what they understand and what they are struggling with.

Moreover, the students are introduced to a three-level simulation related to heat pumps. Level one should be fairly easy to use, level two a bit more advanced, and level three quite advanced. The students will, for example, be asked to make a hypothesis about heat and pressure, and consider the heat effect when getting energy from the earth, water, or air. The entrance to the simulation will be through the Science Hub, and the students' findings will also be logged and reported there. The teacher will sum up the simulation activity using a smart board to visualize the basic concepts and how these are combined in a heat pump.

A final effort to make the students conscious of the concepts and their relationships is to give the students "siftables." This is a new kind of technology where different pieces can be put together in a play-oriented manner. In our case, the siftables represent various components of a heat pump, and the students need to be able to put them in the correct order to make them work. In addition, students can manipulate pressure and temperature by tilting the siftables, and their task is to make the heat pump work effectively.

Finally, students will be challenged to generalize their findings to see whether the principles they have discovered can be relevant to other settings and processes; for instance, in terms of how pressure affects things around us. They will be asked to collect their findings and videos in a report and hand it in as a deliverable for the energy project.

Discussion

In this article, we have focused on how to reconcile play-based learning in the design of a learning trajectory across schools and museums. The design is grounded in a socio-cultural approach. Earlier, we discussed the challenge of reconciling what characterizes socio-cultural play-based and inquiry-oriented approaches to science learning at schools and in museums. Below, we discuss how play-based and inquiry-oriented approaches can inform the design of a learning trajectory across schools and museums, and how the institutional contexts of schools and science museums mediate the design of play-based learning activities that cross these contexts.

We know that play-based activities, stimulating motivation and engagement, are essential for learning (Rennie and McClafferty 2002; Semper, Diamond and St. John 1982). However, museum visits are often stand-alone activities, with little relation to learning activities at school (Griffin 2004). In our design it has therefore been important to integrate the museum visits with pre- and post visit classroom activities (Orion and Hofstein 1994; Anderson et al. 2000; Anderson, Lucas and Ginns 2003). This has been done by combining an inquiry-oriented interpretation of learning by focusing on how play activities in the museum can work as a precursor for development of more abstract thoughts when coming back to school. The institutional context of schools and science museums mediates our focus on the activities that are identified as taking place within the two different settings. In a sense, what we want to design for includes changing the institutional structuring of activities in schools and museums; that is to say, transcending the practices of direct instruction and recalling factual content on the one hand, and engaging in play or drama without reflection, on the other. Having said that, the voices of the stakeholders made these concerns visible, and demonstrated quite clearly that it is crucial to take these issues into account when designing the learning trajectory. In the analytical example, we have shown how the stakeholders in the group negotiated a way to design playful learning activities. The interaction made visible different orientations to the institutional framing of learning activities in schools and in museums.

What is interesting in the analysis and what might constitute a partially shared understanding or idea that can be further developed is the notion of connecting inquiry, storytelling, and meaning making. The contradiction between engaging visitors and designing for more conceptual learning is a common and frequent challenge in museum visits (Anderson et al. 2000). From a socio-cultural perspective of play, we know that students need to perceive what they are doing as meaningful (Roth and Barton 2004). Using stories and narratives might constitute interesting ways for doing just that, since it embeds their activities, even the competitive ones, in a meaningful whole. This is analogous to Vygotsky's (1978) account of children's play where objects are given meaning, for instance, by being embedded in the activity of playing "cowboys and Indians." There is a risk that the competition becomes isolated from the conceptual framework and becomes separated from the science. That is to say, the competition becomes the narrative framework of the activity, or becomes procedurally oriented (Krange and Ludvigsen

2008). In contrast, a storytelling framework related to energy as a topic can more easily be kept as the main narrative, crossing the contexts of schools and museums. Students can, within the same master narrative, explore specific topics like heat pumps in more depth without losing sight of the overall sense making.

In the design, we want to reconcile the activities of playing and learning. That does not mean that we want to blend the learning experiences taking place in schools and museums, as Hofstein and Rosenfeld (1996) argue. Rather, we want the activities of playing and learning to be given prominence at different stages in the trajectory crossing museum and school settings. Thus, what we want to accomplish, and what seems to be reasonable and possible, is to let the various voices of the participants in the project come to the fore at different stages in the learning trajectory. In the beginning, the focus is on engaging students through storytelling and competition, and then gradually this orientation is replaced by a more conceptual orientation when students are working in the school setting. To be able to have an appropriate scientific discourse into the domain of knowledge, students need to combine procedural and conceptual problem solving (Vygotsky 1978; Krange and Ludvigsen 2008). What connects the settings in the learning trajectory are the inscriptions made available through technical means, as the Science Hub inscriptions that students can rework, reinterpret, and connect to the established forms of knowledge and explanations of energy.

However, it is difficult for students to make sense of the scientific concepts by only interacting with equipment and technical tools. It is, therefore, essential to design scaffolding structures to support students' activities (Vygotsky 1978; Bruner 1972; Brown 1992). Introducing storytelling elements is a way of expanding on models of inquiry since the locus of control of the interpretative framework is in the design and not up to the students themselves to construct. Furthermore, teachers' intervention is crucial for the students' learning process (Furberg and Arnseth 2009). Teachers' orientation of students to the relevant objects and concepts in museums and at schools might facilitate students' active engagement in making meanings of scientific concepts. Types of scaffolding should, we argue, be aligned with how students' orientations change from playful interactions with objects to scientific interpretations of the phenomena they have encountered. That is to say, in the beginning, scaffolding can be more about focusing students' perception towards specifically important things in the environment, and towards the end of the trajectory, it can be more about orienting students towards relevant knowledge. In addition, the literature suggests that requests for elaborations and explanations are crucial for developing students' conceptual understanding. The next step in the design process will be to identify the overall narrative for the inquiry, combining play with the learning of concepts for the energy project.

Concluding Remarks

In this article, we have discussed how playing and schooling can be part of the same activity. The design of playful learning activities across schools and museums has been informed by socio-cultural theories of play and learning in science within both settings. We hope that the technological tools, along with teachers' support and scaffolding structures, enable a closer integration between playing and learning, and the social practices of schools and museums. While these have the potential to increase students' learning of scientific concepts, we cannot take for granted that the technological tools will be used in productive ways. This is dependent on how the tools are used within an institutionally framed learning activity, and how the students make meaning of the tools in their collaborative experience.

Further work in the project will provide data on playful interactions and how these interactions may be achieved in conceptually oriented learning processes using a socio-cultural interpretation to learning as an analytical frame. Students will be challenged to engage in inquiry learning by using digital equipment and installations, and a holistic versus a building-block approach will be studied to see how the students engage, play, and learn as they perform an inquiry crossing boundaries between schools and science museums. These studies will inform both further designs of the learning trajectory and the understanding of students' learning of concepts in engaging and playful settings.

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