Chapter 3
Designing for Hybrid Learning Environments in a Science Museum: Inter-professional Conceptualisations of Space

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Abstract This article examines conceptualisations of space in the design of hybrid learning environments. Our focus is the relationship between the task of designing a museum exhibition space and the material and conceptual tools that an inter-professional team of researchers, museum curators and exhibition designers take up, interpret and transform in order to make them serve the team’s purpose. Using Cultural-Historical Activity Theory (CHAT) as a theoretical lens, our purpose is to understand how the tools mediate the task. Understanding the relationship between the physical space and social interaction has become a central concern in the design of hybrid learning environments, i.e. spaces where digital and physical elements are combined to foster immersive learning experiences. Research has focused on exploring the ways users experience designed spaces. However, little attention has been paid to how designers negotiate conceptualisations of space in the design process.

Using video recordings of the interactions of an inter-professional team, we explore how material and conceptual tools mediate the conceptualisations of space in the design of a hybrid learning environment in a science museum. In this chapter, we discuss how the notion of transparency and the prototype of a motion-sensing device became powerful tools in the design of hybrid learning environments. We also discuss how the relationship between the tools and the task has to be understood based on the object-motives of each of the different professional practices. It is argued that a design strategy that includes an understanding of the design process as a cultural-historical process allows for innovative implementations in hybrid learning environments.
3.1 Introduction

In this article, we examine how an inter-professional team negotiates an understanding of a space in the design of hybrid learning environment in a museum setting. Hybrid learning environments refer to the merging of real and virtual worlds to produce new spaces, where physical and digital objects co-exist and interact in real time and across different contexts (Smørdal et al. 2012). Considerations of space are central in the design of virtual worlds, where issues of virtuality and a sense of presence have been the focus of much research (Schultze 2010).

Hybrid environments involve the distribution of computational devices across a physical space, whether these are part of the structure (e.g. interactive walls) or are embedded in it (e.g. mobile devices) (Ciolfi and Bannon 2007). Thus, a regular classroom may be turned into a technology-enhanced setting where students experiment with simulated visual and haptic phenomena distributed across the classroom (Moher 2006). Seen in relation to the design of a museum space, which is the analytic concern of this chapter, technology may mediate engagement by supporting the unfolding dynamics of students’ and visitors’ exploration, reflection, imagination and emotional attachment (Kaptelinin 2011). Information and communication technologies can be integrated with museum exhibits to support re-contextualisation of the visitors’ activities, e.g. by supporting the exhibit with an interactive representation. In the same way the museum space can be re-contextualised by distributing interactive 3-D projections on floors and walls, portions of a larger room may become ‘mini-immersive’ environments (e.g. Bannon et al. 2005). Mobile technologies, such as hand-held devices, web-based platforms and social networks may connect activities taking place in a museum with later activities taking place in the classroom (Jahreie et al. 2011). In all these examples, spaces with a certain history and established practices are re-contextualised with virtual layers that potentially bring about new kinds of spatiality.

Our interest in exploring conceptualisations of space is motivated by recent phenomenological research in interaction design. These studies have introduced the notions of place and sense of place to address subjective experiences of presence, participation and engagement in computer-mediated spaces such as virtual worlds and hybrid learning environments (Ciolfi 2004; Dourish 2006; Harrison and Dourish 1996; Schultze 2010; Turner and Turner 2006). While these studies mostly focus on users’ experiences of already established spaces, our concern is how the concept ‘space’ is negotiated in the design process, and how a sense of place emerges during interactions related to projected spaces. Our analytic focus is on how the designers negotiate conceptualisations of spaces that are made materially present through different means along the design trajectory, including a floor plan, a hand-drawn sketch of an interactive exhibit and a prototype of a motion-based 3D game.

Before we review notions of place and space in interaction design, we will outline our theoretical framework. After the review, we discuss implications for the
design work and then take a closer look at our empirical case and methodology. The empirical analysis is divided in two. First, we have what we prefer to call a socio-historical analysis in which we account for the negation process in the design work. The second part is an interaction analysis of the ongoing negotiations. In the last part of the chapter, we discuss the research questions followed by the concluding remarks.

### 3.2 Theoretical Framework

The concept of *negotiations* is understood from the perspective of Cultural-Historical Activity Theory (CHAT). In this perspective, learning and cognition are seen as object-oriented activities that cannot be studied in isolation from the tools used, the historical practices that frame such use and the goals and motives that constitute them. Drawing on CHAT, we consider conceptual issues involved in the design process not as something pre-structured in theoretical knowledge, but as something achieved in the course of activity and interactions.

We recognise design work as a complex learning activity in which actors from various organisational practices, who have different traditions and domains of expertise, must collaborate in order to develop an object, which in this case is an understanding of space in a hybrid learning environment. The design process involves working outside these established organisational practices (Edwards and Kinti 2010), as neither the object to be accomplished nor the means to achieve it are defined in any prescriptive manner. Instead, the different actors must negotiate the nature of the object and how it should be materialised. By focusing on the goals and motives of an activity, CHAT allows us to go beyond phenomenological and situative explanations of how space is experienced and enacted to include the horizons of possible actions for inter-professional teams to understand and design hybrid spaces in museums.

Three notions related to CHAT that are of particular relevance to our study are objects, tools and boundaries. The notion of object is the core concept in CHAT towards which activity is oriented. In this study, the focus is on how the designers negotiate an understanding of space in a hybrid learning environment. The object is in a constant state of transformation and is questioned, interpreted and negotiated during the design process (Engeström 2008). The meaning of the object is an inextricable part of the activity. The notion of object has a dual disposition: material and ideational. The object is realised through activity in which the activity is simultaneously formed by the actors’ negotiations of the object (Kaptelinin 2005). In our case, space for hybrid learning environments is materialised in the form of a model of a museum space and a museum exhibit, and space in hybrid learning environments is conceptualised in terms of ideas and suggestions, which are in constant negotiation. In this study, we see how understanding of space is realised through the design work and how the object also brings about transformed practises.
Cultural tools shape the way we learn (Cole 1996; Vygotsky 1978). As objects, tools have a dual disposition as material tools (as models, images, prototypes, plans and timelines) and ideational tools (concepts and language). Tools mediate our actions, and the use of tools helps actors make sense of objects. The relationship between tools and an object captures the dialectical process of learning and development (Vygotsky 1978). Tools are vital when characterising design work and are often provided as part of the design (such as the exhibition plan or model of a museum exhibit). The tools serve to coordinate actions in specific ways and mediate the way team members make sense of the object. At other times, team members pick up tools that were not initially part of the design and make them serve their needs (Lund and Rasmussen 2008). The design of technology-rich environments, such as the one currently studied, affords multiple tools, but the question exists: which tools are actually picked up and put to use in object-oriented endeavours?

Design work involves moments for participants in which individual interests become aligned with those of the team’s. Individual interests originate in their primary activities in museum, architecture and research centres. The boundaries within the team become problematic places where different sets of practices come into contact (Kerosuo 2003). The boundary work is seen as an important aspect of inter-professional activity.

Since collective orientations across different professional practices are central in inter-professional work, boundaries are a key concept. Boundaries are part of the activities and have historical layers. They are intrinsic to the professional practices, but become transparent in and through participants’ interactions (Kerosuo 2006). In design work, one can imagine that the team negotiates an understanding of the borders of the professional practices. In transcending the boundaries, participants encounter different and sometimes conflicting meanings of the task or object; thus, processes of collective concept formation are imperative. Design work depends on the expertise and knowledge of each of the professions. Therefore, to succeed in the design work, collaboration and negotiation of the object is vital. In such collaborative work, there are continuous breakdowns and contradictions between competing organisational options. As several studies have shown, such tensions and contradictions are productive for design work and may shift the path of the activity (Engeström 1999).

Drawing on CHAT, our concern is the relationship between the object and the material and conceptual tools. In the analysis, we trace instances of explicit and implicit conceptualisations of space in order to explore how these conceptualisations are mediated by different material and conceptual tools and the ways in which the tools become relevant to the teams’ shared task. Based on this background, we pose the following two questions:

- How do material and conceptual tools mediate conceptualisations of space in the inter-professional collaborative design of hybrid environments?
- How do conceptualisations of space transform the design of hybrid environments for the inter-professional team?
3.3 Notions of Space and Place in Interaction Design

Notions of spatiality are central to most definitions of virtual worlds (Bell 2008). From a classical approach, an aspect of spatiality in the virtual realm relates to its subjective character: unlike a physical space, a virtual space is not a space in its own right (Heeter 1992). The subjective character of the space is contrasted with the ‘objective’ features of the environments, such as the degree of representational fidelity or of sensorial richness (de Freitas et al. 2010). This approach, therefore, assumes a separation between the physical and the psychological.

Phenomenological researchers have critiqued the classical approach (e.g. Ciolfi 2004; Mantovani and Riva 1999; Turner 2007). For these researchers, the problem is considered a question of engagement and intentionality in activities. Spaces are always mediated by cultural aspects and become meaningful for action and interaction with others. In line with these critiques, the notion of place has been increasingly adopted in interaction design literature in order to address issues of spatiality. Harrison and Dourish’s discussions on place have been particularly influential (Dourish 2001, 2006; Harrison and Dourish 1996). The concept of place arises from the realisation that our behaviour within space cannot be explained exclusively by the relationship between the physical spatial arrangements of matter around us and the individual’s mental processes, rather it necessitates consideration of the social meanings and practices related to them (Dourish 2001). Thus, drawing on the notion of place, space is understood in terms of its physical, subjective, social and cultural dimensions (Ciolfi 2004; Ciolfi and Bannon 2005, 2007).

The implications of adopting a notion of place in the design of virtual worlds and hybrid learning environments include a shift in focus from features of the environment that may convey a sense of presence to focusing on the ways in which designed spaces may support the development of social activities that are the foundation for developing a sense of place, i.e. being a participant in meaningful action. Within this framework, much current research on virtual worlds pursues an understanding of the processes through which virtual spaces become places of meaningful experience or third places for social interaction (Peachey 2008). This conceptualisation attends to the discursive practices that bring about a sense of community (Chap. 5 by Ferguson et al., this volume) and to the nature of the narratives that frame engagement in a given environment (Turner et al. 2005).

3.4 Implications for Design Work

Notions of space and place have mostly been discussed in regard to users’ experiences of computer-mediated environments, often with the goal of improving design. The design implications bring about a focus on the interactional processes through which users render spaces meaningful to social conduct; this focus prevents us from drawing simplistic a-priori relationships between a computer-mediated
environment and users’ subjective experiences. Some researchers have developed a framework for designing hybrid spaces in museums based on notions of space as place (Ciolfi 2004; Ciolfi and Bannon 2005, 2007). Drawing on the notion of place, these researchers understand space in terms of its physical, subjective, social and cultural dimensions; museums are seen as ‘lived places’ where the design of an exhibition accommodates visitors’ sense of place and historical aspects of the museum space.

However, defining sense of place as an interactional achievement does not render design work incapable of foreseeing hybrid learning environments as lived-in places prior to their actual population. Ciolfi and Bannon’s works discussed above, for example, stress the importance of conducting ethnographic investigations of the practices that take place in a physical space prior to implementation of design in order to get an understanding of the kind of social processes that are to be supported. Yet, little attention has been paid to the question of how a sense of place comes to be in a design process prior to the existence of a given place itself. An exception is Binder et al. (2011), who note that if we assume spaces must be appropriated by the users to become meaningful places, ‘then we must assume that this is true for designers as well with regard with their environments’ (p. 139). They emphasise the peculiarity of design work in which the object (space) to be designed does not yet exist. The authors use the concept of landscapes to emphasise the importance of grasping the double nature of design as both a situated practice and a hypothetical practicing of an imagined place (Binder et al. 2011).

In this chapter, we take up the challenge of understanding the emergence of a sense of place in the course of the design. We analyse the interactions of an interprofessional team that collaborates to design hybrid learning environments across the school and the museum. As we mentioned in the introduction, negotiations of various object conceptualisations are vital for success in inter-professional work (Engeström 1999). Therefore, in addition to negotiating the very nature of learning, designing hybrid learning environments may involve negotiating conceptualisations of the lived space as an object of the ongoing design work and as an imagined or projected lived space in the museum.

### 3.5 Context Description and Methods

Data for this study were generated from the project Mixed Reality Interactions across Contexts of Learning (MIRACLE) (Jahreie et al. 2011). As it makes use of technologically enhanced physical spaces, MIRACLE aims to increase students’ interest in and conceptual understanding of science by connecting science education learning activities in upper secondary schools to activities at a science museum. MIRACLE is connected to an exhibition that is to be designed at the Norwegian Museum of Science and Technology (NSTM) called ‘Energy for the Future’. This exhibition is part of a redesign of the whole museum. Energy is one of the main themes in the curriculum for the upper secondary freshmen year. Heat pumps,
on which we focus in the first of three iterations, are one of the central sub-themes (Norwegian Ministry of Education and Research 2010–2011). The core tools in the design process in this first iteration are the development of a pedagogical plan, a technological plan and a museum exhibition plan. These plans are developed in parallel, but relate to each other. The participants have responsibilities in different plans, which are discussed and negotiated in the workshops. In the data gathered for this study, the focus for discussion was mainly the exhibition plan, although it was seen in relation to the other two plans.

MIRACLE involves a complex design process motivated by a set of workshops with different relevant stakeholders, such as museum conservators, exhibition designers, researchers, scientific programmers, teachers and animation specialists. Because participants are from three different professional arenas—a science museum, an architecture firm and an educational research centre—we refer to the different participants as curators, exhibition designers and researchers. Researchers include educational researchers and scientific programmers, as they share the same workplace and environment.

The study is based on observations from the first year of the project (October 2010–November 2011). During this period, we conducted five design workshops in which the different partners met to discuss and negotiate different development concepts. Some of the technological solutions in development were tested in a first pilot study. Workshops I–IV were used for the ethnographic contextualising of data. All workshops were video recorded, which produced 14 h of material. The analytic work was conducted in three steps. First, we constructed an overview of the total corpus of data in order to select a subset. Second, we conducted an initial analysis to identify recurring patterns of interaction. In the ethnographic analysis of the socio-historical development of the project, we identified two recurring themes, which are discussed in the following section. In Workshop V, which is documented in 5 h of video recordings, we were able to identify specific instances where the team made sense of the exhibition space, and we selected two excerpts for deeper analysis. In addition, a third excerpt was extracted from the pilot study conducted in November 2011. This latter excerpt was selected because discussions on space took place within a full-size prototype of the projected space. The iteration is documented in 2 h and 25 min of video. Our analysis builds on interaction analysis (Jordan and Henderson 1995). Both Workshop V and the iteration were conducted in English. It is important to note that most of the participants were not native English speakers and that we have retained the original phraseology in the transcripts.

As researchers, we participated with our colleagues in the group studied; therefore, caution is necessary. Our own voice should not be more weighted than the others. In effect, this means we are not looking for some kind of normative idea about the right way to design and develop learning activities in science, rather we hope to identify how the team negotiates central themes in the design work. In accordance with methodological standards (Jordan and Henderson 1995), we used our socio-cultural research community to objectify our analysis to make sure we dealt with the different voices equally.
3.6 Empirical Analysis

3.6.1 Socio-historical Development of Negotiations in Inter-professional Design Work

The initial analysis revealed two recurring themes present in the negotiations in Workshops I–V. The first was experience versus the reflective aspects of learning. Based on observations from Workshop I, our initial analysis of experience and the reflective aspects of learning as a recurrent topic confirm the findings of a previous study (Jahreie and Krange 2011). The participants focused their attention on the same object, designing learning activities across schools and museums, but there was tension regarding the object conceptualisation. The curators were inclined to perceive learning as an interactive, engaging experience, whilst the architects perceived learning in terms of emotional involvement, and the researchers perceived learning as conceptual understanding. This is not surprising, but what is important is that the different conceptualisations were mostly seen as separate, and the integration of these orientations into a shared understanding remained a challenge (Jahreie and Krange 2011).

A second recurrent tension identified concerns the knowledge domain of energy. Energy as a theme involves both scientific (related to physics) and socio-political issues. Both issues are part of the curriculum (Norwegian Ministry of Education and Research 2010–2011). This topic was repeatedly discussed and negotiated in relation to the heat pump sub-theme during the workshops. In the negotiations, we found that exhibition designers often found the scientific issues of heat pumps to be problematic topic in the museum space. However, researchers were more concerned with fostering students’ conceptual understanding of scientific aspects and paid less attention to the socio-political issues. Finally, museum curators clearly showed sympathy for the idea of including scientific-related curriculum issues, but often criticised the heat pump theme for being too complex to be understood beyond its socio-political dimension in the museum setting. What is interesting in this discussion is that the participants often discussed scientific and socio-politic issues separately; thus, their interrelation in the design layout became yet another challenge.

In this ethnographic contextualisation, we identify different orientations to the two recurring topics. As indicated in our first study of the design process, these differences must be understood in relation to conflicting object-motives between practices (see Jahreie and Krange 2011). Through the lens of CHAT, this situation can be identified as one of contradictions (Engeström 2001) between different conceptualisations of the generalised object of designing for learning activities on one hand, and between understanding how the knowledge domain should mediate the object on the other. Until Workshop V, the participants tended to defend their orientation, which was grounded in both their motive for participating and the division of labour in the inter-professional group.

In the following sections, we examine how tools mediate new conceptualisations of space at the boundaries of the inter-professional team.
3.6.2 The Exhibition Plan: Space as a Shared Object

In the first part of Workshop V, the two exhibition designers presented a draft of the exhibition plan. The plan was displayed in a series of PowerPoint slides. The room depicted is square and covers 120 m$^2$. It is a small space for an exhibition, which makes it challenging in terms of the architectural design. The solution suggested by the designers involved setting a corpus of modular walls in the centre of the room to form a number of modules (Fig. 3.1).

The modules were intended to house the different exhibits, individuating each one as unique. At the same time, because they are not closed, the modules are still connected to the rest of the room. Apart from a lack of space in the room, the design highlights two other possibilities in the plan presentation. One is related to the interactivity of the room: ‘When you enter an exhibition, you want to meet eyes; you don’t want to meet backs. We wanted to focus the exhibition to the core of the space and not to the walls’ (exhibition designer). The other involves the challenge of relating the different sub-themes of the exhibition to the overall Future of Energy theme. Thus, a number of solutions were presented to increase the sense of unity. The space dedicated to each exhibit extends beyond the modules up to the external walls of the room, and a single material is used for the entire floor up to the walls. The draft design also includes the possibility of streaming media that is being projected from each module on the external walls, so that what is going on within each exhibit is shared or reflected in the open, shared space.

After a 15-min presentation, the participants discussed the exhibition concept. The matter of how the modules relate to each other, how they are related to the rest of the room and how the room relates to the rest of the museum became a topic of discussion. In Excerpt 3.1, the participants discuss the possibility of having transparent, interactive walls.

Fig. 3.1 The plan floor presented by the exhibition designers during Workshop V
Excerpt 3.1

1. **Researcher 1**: One comment. Eh, I liked very much what you said in the beginning with the, eh, not seeing all these backs. When you come into a space, you see only the back heads of people who are working. But still this is a kind of box. Like a black box things set up. Could it be an idea to have some kind of transparent, eh, transparency there? Because you have issues, each, eh…

2. **Exhibition designer**: We are talking about using these corridors (*pointing to the screen*) of course here is a physical corridor where you can walk in, you see people that you’ve seen before… which is…

3. **Researcher 1**: …Because it could also be an illustration of that it’s not only one solution. It’s not only sun or only wind, it’s a common thing and there are certain different things.

4. **Exhibition designer**: Yeah, and how you connect this one, this one and this one (*pointing to the different cabins*) when you make a transparent window in between and we start using mirrors, where you instead of projectors use mirrors to…

5. **Researcher 1**: Because one thing we thought about is also to have a projection, if you combine this bicycle idea with a projection, it could be interesting if people also are in the other side, so you see kind of semi-transparent projector material that you can look from different sides.


7. **Researcher 1**: Yeah

8. **Curator 1**: It’s possible on that wall, but not on the other wall.

9. **Exhibition designer**: Which one is that and which one is the other?

10. **Researcher 1**: It is not possible in the walls around…?

11. **Curator 1**: Is this one… (*Pointing at the powerpoint*)

12. **Researcher 1**: Ok, so then it’s possible

13. **Curator 1**: And … and this one is facing, facing out into the science center. And this one is facing into a corridor for the engine room for the elevators.

14. **Researcher 3**: Because if you think of this as a kind of an extension of the science center now, it will kind of have the same feeling, what it’s in this space …

15. **Curator 2**: It will have, it will be all interactive, but it will have a different form. And it will connect to this big master plan of the future energy… so it will be part of that.

16. **Researcher 3**: Yeah
At the beginning of the excerpt, Researcher 1 refers to the exhibition designer’s presentation of the exhibition plan. When someone enters an exhibition, they usually see visitors facing exhibits on the walls and therefore see only their backs (turn 1). Researcher 1 thus acknowledges the exhibition designer’s previously introduced idea of designing a space where the focus is on the centre of the exhibition space and not on the walls. However, he is concerned that the design of the space may remain a ‘black box’, and suggests that one solution might be to design some transparent walls. Since the focus in the conversation was on the modular walls at the centre of the room, it is reasonable to infer that Researcher 1 is talking about transparency as a means with which to connect the modules. The exhibition designer argues that due to the design of the physical corridors, visitors can meet each other and the corridor will therefore prevent a box-like feeling (turn 2). Researcher 1 interrupts the designer and argues that transparency would also be a way to illustrate that energy relates to both solar power and wind power (turn 3). Transparency would then be a means for visitors to connect the different exhibits from each module. With this utterance, the researcher picks up the designer’s challenge of integrating the sub-themes related to energy. The exhibition designer seems enthusiastic about the suggestion of transparency between the exhibits. He points to the screen showing the exhibition while explaining that with transparent windows they will be able to design a connection between the exhibits. The exhibition designer is in the midst of arguing for the use of mirrors instead of projectors, when Researcher 1 again interrupts him. The researcher brings a new dimension into the conversation. He suggests that using a projector makes looking at a semi-transparent projection of the exhibit from different sides possible (turn 5). Transparency is not only a solution for integrating the different exhibits, but also for opening the interaction to people outside the modules. The researcher is supported by another researcher who suggests a double-sided screen. Curator 1 then enters the conversation to tell the others on which walls it is possible to have transparent screens (turn 8). In turn 9, it becomes obvious that is not clear to which walls he is referring. Researcher 1 asks if it is possible ‘in the walls around’, signalling that he is unsure of the walls to which Curator 1 is referring. This shows there is more than one possible interpretation. This interchange represents a turning point, when the focus of the discussion is reoriented toward the walls around the room and not those between modules. Based on the explanation of Curator 1, Researcher 1 concludes in that turn 12 ‘then it’s possible’. Researcher 3 takes up the idea of Researcher 1 and argues that the use of transparent walls makes it possible to see the exhibition space as an extension of the science centre. Curator 2 seems to think it is a good idea because transparent walls are a way to design for interactivity and because the solution is part of their overall plan for the Energy of the Future exhibition.

One main issue concerns the role of material and conceptual tools. In the interaction, we see how the participants take up multiple tools that afford different conceptualisations of the object. First, conceptualisations of space are facilitated by the presentation of the exhibition plan. The material presence of the museum’s projected space, in the form of an exhibition plan, affords an interaction where the
participants can physically and verbally point to different aspects. In referring to its different structural aspects, the participants simultaneously refer to interactions that some suggested scenarios could afford. Therefore, an exhibition plan has a double nature that mediates the object in different ways. First, the exhibition plan consists of a physical artefact in the form of a PowerPoint slide, which allows indexical referencing in the discussion. Second, the exhibition plan has a projective nature in the sense of being a draft in a design workshop. In this sense, it is understood not as an end product to be interpreted, but as an occasion for inspiration and suggestion. As different participants verbalise these ideas, space for negotiation is opened.

Another issue is that space is inherently treated in terms of affordance for interaction within the projected space and also as a means for solving conceptual tensions within the project. The structure of the modular space facilitates the introduction of the notion of transparency, which in turn generates ideas for how to design for interactivity within the exhibition space. Two aspects are particularly interesting in this respect. First, the idea of a transparent wall between exhibits is related to how to understand the topic of energy (turns 3–4). Transparency offered the possibility for negotiating the nature of the knowledge domain of energy, a topic that represented one of the main tensions for the team in previous workshops. In this sense, the concept of transparency seems to provide opportunities for a more open and integrated discussion of energy as an interrelation of scientific and socio-political issues. Second, the idea of transparent walls between the exhibition and the science centre (turn 14–16) seems to generate new ideas about how to thematically link the different parts of the museum. This would afford an integral participation trajectory within the room and across the museum and a means to solve yet another potential source of tension in the inter-professional team: designing a thematic space within the larger museum.

We also see that the participants use other tools, such as mirrors and technology-based resources, to further generate ideas about how transparency affords interactions within the space: between visitors (turn 1), between exhibits (turns 3–4), within an exhibit (turns 5–6) and between different exhibitions within the museum (turn 14).

The second main aspect we want to highlight is how space evolves as a shared object in the inter-professional team. The exhibition plan and the concept of transparency afforded the negotiation of a shared vision of a possible space, beyond what was represented in the plan. On one hand, we see, not surprisingly, that the exhibition designers introduce a typical architectonic device, mirrors, as a mediating tool, while the researchers are concerned about how digital devices can mediate the space.

Designing a museum exhibit that links a material exhibit with a digital device is introduced by the researchers. This is an important design issue for the researchers. However, even more interesting is that the researchers also introduce a discussion of an overall museum design by considering the new exhibition as an extension of the science centre, which is of interest for the overall re-design of the science museum.
3.6.3 Space as Topic: Tensions Between Tools and Object

After the exhibition designers’ presentation, participants from the research group made a presentation in which several possible technological solutions were proposed. Excerpt 3.2 is taken from a group session following that presentation. The team is divided in two inter-professional groups for discussion. The aim is to discuss the proposed scenarios and to come up with ideas about how to combine technology, the exhibits and exhibition activities. The group we follow discusses the heat pump exhibit. The participants’ interaction is in part mediated by an image of an exhibit and an associated hand-drawn sketch of an interactive heat pump model. The image and the model are displayed on a laptop visible to all participants (Fig. 3.2). The model is a tool provided by the researchers for the design work.

Excerpt 3.2

1. **Researcher 3**: I am just wondering, you know, what we could do with this thing here (pointing to the displayed image) in terms of engagement, embodiment, mixed reality… mmm, ways of unpacking the heat pump.
   [all they stare at the screen in silence for a while]
2. **Curator 2**: “What’s going on down there?” (pointing on the exhibit artefact). That’s the black box. If you can put it up here (pointing to the heat pump model), and you have some images, or a way to explain it or show is better…
3. **Researcher 3**: If we discuss not on heat pumps, but on more hybrid spaces that are both physical and digital and mixed… Because that has an architectural issue, I think…
4. **Exhibition designer**: (long silence) Yeah, but I don’t think it’s from that angle. It could be anything. But I think it has to start with…Architecture is mostly sometimes in a way sight specific, as well as sight is not only into space but is also topic. And we have to work with a topic. And how media and architecture interact is not a topic. So you have to start with what issues or what target group, or… are we gonna work from or with.
5. **Researcher 4**: Right, so you are saying that you can’t just take any old exhibit and put into that space…
6. **Exhibition designer**: In my world I would like to work with what story are we gonna tell, what are we gonna communicate, why are we gonna do this. And I do not work out of “Ok, I love this chair, and now I am gonna find a room where I can fit this chair in, cause that it’s not how I do. Product designers work like that. And that is another angle. And is like the technical and the political…
7. **Researcher 3**: But could that be translated into this one (pointing to heat pump representation).
At the beginning of this excerpt, Researcher 3 invites the others to generate ideas about how to facilitate students’ ‘engagement’ with the understanding of the principles behind the heat pump. He mentions resources such as ‘embodiment’ and ‘mixed reality’. Curator 2 fixes his attention on the model of the heat pump. He points to what he defines as the ‘black box’ in the model and suggests it be ‘unpacked’ or explained by representing it as a projection in which they can use, for example, images as a way to explain it better (turn 2). Researcher 3 takes up the curators’ idea by reframing the question to consider hybrid spaces or mixed realities. By stating that he thinks there is ‘an architectural issue’, he is addressing the exhibition designer. The exhibition designer replies that from an architectonic perspective, one should focus on the topic of space when designing an exhibition. To be able to solve the problem, they need to work with a topic, and the interaction between technology and architecture on which the researcher focuses is not a topic (turn 4). Researcher 4 backs the designer up and rephrases the designer’s comments, stating that the focus should not be the artefact. The exhibition designer acknowledges Researcher 4 by stating that the subject of the communication must be the focus of the architectonic design and not the exhibit or artefact itself (turn 5). The exhibition designer confirms that it is the topic that must be communicated. He explains that, as architects, the intention is not to choose an artefact and then designing an appropriate space to house it. Researcher 3 then asks how that can be translated to fit their heat pump model (turn 7).

In this excerpt, different approaches to students’ learning activities in the museum space are discussed. In Excerpt 3.1, a plan for the exhibition in the form of a material tool mediated the interaction between participants. In this group work, there is no
material representation of the space. Instead, a model of the heat pump stimulates talk of how to design the museum space. An important aspect in this interaction is tension between the tools and the object. The tension is related to whether the technological means (turn 3) or the topic (turns 4 and 6) should mediate the design of the spatial distribution for this particular exhibit. The researchers are concerned with how to design technological representations and hybrid environments that facilitate learning activities. In their account, the conceptual aspects related to the knowledge domain become relevant for the material distribution of space. Whereas in the exhibition designer’s account, the story one wants to communicate through the exhibition is made relevant.

To understand the tension described, we have to examine the impact of historical practices on the current interaction. From this perspective, it is fruitful to understand the interactional tension as a contradiction between two professional practices. The researcher and exhibition designer foreground their knowledge, the former in technology design for learning and the latter in the spatial affordance for communicating a topic in a museum exhibition. Even though we see instances where the researcher tries to integrate the two forms of knowing, they are not able to find a common ground during this interaction.

### 3.6.4 Being There: Tensions Between Museum Exhibits and Technology

Excerpt 3.3 is from the first iteration that was conducted in a studio at the University of Oslo, where a classroom space and a museum space were set up. The aim was to test some of the technology-enhanced scenarios in development. At that point in the design process, motion-sensing technology was suggested to represent some of the key concepts of the heat pump in an interactive game. A full-size mock-up of one of the modules projected in the exhibition plan and described in Excerpt 3.1 was built to house the motion-based game (Fig. 3.3). The game is designed for two players who must stand within the module to activate it. The players are represented by avatars in a 3D projection on the wall. The players’ movements are replicated by the avatars in the virtual space. Players must interact with some of the virtual objects in order to heat up a virtual house. The rationale of the game follows some of the physical principles of a heat pump.

We enter the conversation in Excerpt 3.3 just after a museum curator and an exhibition designer have tried the application. Without leaving the experimental space, the researchers initiate a discussion based on the impressions of the museum curator and the exhibition designer. Just before we come into the conversation, the exhibition designer suggests that including material objects as part of the game would improve the experience in different ways.
Excerpt 3.3

1. **Exhibition designer 2**: and not just weaving around in the air (*waves arms*) but actually touching objects.

2. **Curator 1**: yeah. that’s an interesting point because that also bridges the classical museum exhibition and this-

3. **Researcher 5**: digital, 

4. **Curator 1**: -game thing that you can do anywhere.

5. **Exhibition designer 2**: mmm,

6. **Curator 1**: if you, if you construct something here in the middle of this room. eh if it’s not obstructing this, if it’s possible, then you can both get to touch of the physical object, and then you also, you also make the point that this actually brings eh something new and better into the museum exhibition. Because traditional museum exhibitions will just show this (*shapes spaces where he has suggested that physical objects should be placed*). But here you could actually explain it in a way.

7. **Exhibition designer 2**: mmm.

8. **Software engineer**: mmm.

9. **Exhibition designer 2**: and then it leads into a very, an interesting discussion about purpose with the eh, this imaginary virtual space (*pointing to the wall where the game is projected*).

10. **Researcher 5**: yeach?

11. **Exhibition designer 2**: what can you do there that can’t be done in reality or with physical objects.

12. **Researcher 5**: mmm.

13. **Curator 1**: (*pointing to game projection*) and I think that-

14. **Exhibition designer 2**: so of course this is, this is an eye catcher and eh an exhibit that will probably draw attention if, at least until every kid has their own-

15. **Researcher 5**: their own kinect,

16. **Exhibition designer 2**: xbox at home, so-

17. **Curator 1**: but they won’t, what they won’t have in their room is the physical objects here (*shaping the space where the physical objects are suggested to be, again using the same gesture*). for instance, if we have a heat pump, or if we have a turbine or something, we can do also museum objects here. that would be the specific thing about the exhibition, when you both get a hands-on explanation of, of cultural technology and real objects, and you at the same time have the playfulness of this (*pointing to the wall where the game is displayed*) which you of course don’t get in our traditional energy exhibition. because they are just a display of death objects. but here you can bring the death objects alive as well.
The excerpt opens as Exhibition Designer 2 emphasises his point about including material exhibits in the game, as this gives an opportunity for actually ‘touching objects’. Curator 1 adds that it is interesting because it connects ‘the classical museum and this…’ Researcher 5 interrupts, and says ‘Digital…’ (turn 3). Curator 1 continues with ‘game’ and adds ‘that you can do anywhere’. It is reasonable to infer that the curator was also thinking about enhancing traditional museum exhibitions with digital technology in turn 2. The exhibition designer seems to agree, and Curator 1 elaborates on how to include material exhibits within the game, illustrating with his hands as described in turn 6. He lists two advantages. The first is the personal learning experience for the visitor: they can both touch something and have an explanation. The other is related to the museum’s reputation; it will change the traditional role of museum exhibitions (turn 6). Exhibition Designer 2 and researcher 5 agree (turns 7–8). The exhibition designer discusses the opportunities the virtual space gives, compared to traditional museum exhibits (turns 9–11). He adds that it will be an eye-catcher and will attract significant attention. However, he seems worried that this will just be temporary until motion-sensing devices are common in private homes (turn 14). Curator 1 argues that even though people will eventually have such digital devices at home, the museum will have the advantage of relating motion-sensing devices to exhibits. The digital device will be experienced as ‘playful’ by the visitors and is a way to bring museum exhibits ‘alive’. This reinforces his previous statements.
Of interest in our analysis is how being immersed in a discussion about the object relates to the way the object is approached. The participants discuss space distribution and where to put material exhibits within the space in which they are materially situated. Some of the elements to which they refer are present, such as the wall where the game is projected, while others are absent, such as the material exhibits they might place within the module. In this way, the prototype of the space becomes a tool that mediates the conceptualisation of the object space. The prototype affords the participants an experience of the space in an embodied manner, in which they can act both as visitors and designers. By being placed in the subjective experience of space, new aspects and ideas not yet raised in previous discussions emerge.

A second aspect of relevance is how the inherent tension between the historical role of museums and the emergent role of technology within museums is emphasised and negotiated in the design process. The participants build on each other’s statements to elaborate on the possible relationship between the traditional material museum exhibits and digital devices. The advantages of designing for such relationships are discussed on two levels. First, it will improve the visitors’ museum experience. In the discussion, the digital enhancement of the physical experience is seen as a means to visualise the knowledge underlying the hypothetic material exhibit. In this way, the prototype of the space (the tool) mediates the object (the conceptualisation of the museum space) as a place for experience, fun and learning. Second, being placed within the tool prompts a discussion of the conceptualisation of space at an institutional level. Designing a museum space where digital devices are used in relation to museum exhibits will be a means to enhance the traditional design of museum exhibitions.

### 3.7 Discussion and Concluding Remarks

Our aim in this study was to explore how material and conceptual tools mediate the conceptualisation of a museum space in inter-professional design work, and how the conceptualisation of space transforms the design work. We have seen how negotiating and co-constructing a vision of the museum space has encompassed the development of a shared understanding of particular ways of “being there” in an immersive learning environment, as well as the development of general forms of learning in a science museum. In the team’s discussions, the physical space was primarily treated as a set of affordances or means for supporting interactivity. Experiential, social and cultural dimensions were acknowledged, as participants discussed social interactions, feelings and expectations related to being within the different imagined spaces. However, the participants took different approaches to the object. These approaches were inherently related to how knowledge is conceived in their individual professions.

In the first research question, our concern was how tools mediated the interprofessional team’s conceptualisation of space. Previous studies within CHAT have provided substantial evidence of the importance of using tools, both material
and conceptual, as mediating objects to succeed in collaborative work (Ellis 2008; Engeström 2007; Engeström et al. 2005). An important aspect is that a single tool does not mediate the design of hybrid learning environments, but rather a constellation of tools are needed in design work (Engeström 2007). Thinking is done in using the tools, and the analysis shows how different tools afford different object conceptualisations. Furthermore, we have seen that the constellation of tools was both material and conceptual and that some tools were provided as part of the design work while others were picked up by the participants during the interaction (Engeström 2007; Lund and Rasmussen 2008). The analysis shows how the exhibition plan, a tool provided as part of the design, made it possible for the participants to pick up new conceptual tools, such as the notion of transparency, mirrors and projection, in the conceptualisation of space.

What we find interesting is the type of epistemic work the tools accomplish in a given interaction. In the analysis, we saw that the notion of transparency and the prototype of the motion-sensing device became the most powerful tools in the design of hybrid learning environments. These tools opened up a landscape of applications (Engeström 2007). Some of them were outside the initial scope of the project, such as how to transform the museum itself. First, the notion of transparency worked as a means to talk about one of the most debated topics during the design work, how to present the knowledge domain of energy. Second, when the concept of transparency was introduced, it generated ideas about how to link the traditional museum exhibit with a digital device and thematically link the different parts within the exhibition itself and between the science centre and the museum, which until now have been two separate parts within the science museum as a whole.

The prototype of the motion-sensing device was particularly interesting since the negotiation of the hybrid learning environment took place within the actual space. Studies of technologically mediated learning environments typically introduce new digital tools that are ready to use and thus cannot be developed further (Engeström 2007). In the design process, we introduced the technological tools as prototypes, where reconfiguration of the given technologies was an essential part of the design. Instead of getting situation-specific feedback, which is often the case with ready-made technologies (Engeström 2007), the analysis showed that the prototype generated a rich interaction about how to improve visitors’ experience with respect to learning and play and about how to improve the design of museum exhibitions in general.

Our second research question was how the conceptualisation of space transformed the design work of the inter-professional team. The ethnographic contextualisation of the first four workshops revealed contradictions within the object and between the tools and the object, and participants defended the boundaries of their respective activity systems (see also Jahreie and Krange 2011). However, in Workshop V, we identified an important turning point when space became a shared object in the participants’ interaction. The object’s construction has to be seen in relation to the type of epistemic work done with the tools in the interaction. In the analysis, we saw how the notion of transparency and the prototype became powerful tools for the conceptualisation of space. These tools afforded shared ideas about
how to present the knowledge domain, how to link material exhibits and digital devices and how to link the science centre with the museum exhibition. In this way, the shared conceptualisations of space transformed the design work of the inter-professional team. Based on the analysis, we can identify two important instances of boundary transformation, which could have caused tension or a breakdown in the team meetings (Kerosuo 2003). The first aspect is related to the design of an overall plan for NSTM. Designing an overall plan for NSTM that links the science centre with the museum exhibitions is not part of the MIRACLE research project, but it is an important focus for the museum curators and the exhibition designers in the future design of NSTM. On this basis, it is interesting to see that the researchers expanded the object by introducing the idea of transparent walls between modules and within an exhibit as a means to link the different exhibitions within the science museum and between the museum and science centre. This re-contextualisation of the museum space may be relevant in regard to how one understands hybrid learning environments in museums, since it gives opportunities for re-negotiating how learning in museums should be understood (see Jahreie and Krange 2011).

The second aspect is the design of technological-enhanced exhibits. Designing technological tools that mediate the museum exhibits is important for the MIRACLE project’s motive of enhancing students’ science learning between school and museum. This object-motive was accounted for by the researchers in the discussion of transparency in Workshop V, and was picked up again by one of the exhibition designers and museum curators in the pilot study 3 months later when they tried out the prototype. What is especially interesting is that the museum curator now sees this as an opportunity to improve museum exhibitions in general, thus generalising the object-motive of the researchers to an understanding of how the science museum may redefine or expand its institutional role of knowledge curation and dissemination.

However, the analysis also showed that not all the tools were powerful enough to extend the negotiation of space. The model of a heat pump, a tool provided by the researchers as part of the design, was discussed by the researchers, but it was not picked up by the exhibition designers or museum curators. To understand this, we need to take a historical perspective regarding the object-oriented activities. How we come to knowledge depends on how we take part in collective activities that evolve over time, and where conceptual and material resources function as collective structural resources (Engeström 1987; Valsiner and van der Veer 2000). The introduction of the heat pump model mediated historical contradictions about how architects and researchers conceptualised the design of the museum space. This contradiction has to be understood based on their professional knowledge of designing space and designing digital devices for learning.

In summary, the interactions observed revealed important instances in which the team negotiated shared conceptualisations of space that went beyond boundaries and thus transformed the object-motive of the researchers, museum curators and exhibition designers. While the nature of learning may be an abstract matter, it became tangible when considered in relation to the material features of space. In making such a conflict relevant to the core of the project, new opportunities for transforming the design work emerged.
This study also has implications for how to approach the design of hybrid learning environments. In our review of notions of space in interaction design, we showed that a phenomenological approach to space emphasised the physical, subjective, social and cultural aspects of being in a place. In turning attention towards the ways in which space is conceptualised in design work, we aim to expand the discussion to also include the relationship between spatiality and social interaction. This is accomplished by addressing the ways in which this relationship is also relevant to the projective facet of design, which is devoted to creating spaces that do not yet exist. In line with the landscapes notion of Binder et al. (2011), we contend that inherent in the design process is a multiplicity of possible conceptualisations of hybrid spaces. However, while this notion grasps the double nature of design as both a situated practice and an imagined place, it does not take into account the cultural-historical dimensions of the conceptualisations of the object. As we have seen in this chapter, designing hybrid spaces often involve collaborative work with participants from various professional practices, each bringing a historical way of conceiving the object (Edwards and Kinti 2010). We suggest that the generation of innovative design solutions to support immersive experiences in technology-enhanced spaces can be improved upon with a deeper understanding of the tensions involved within and across the historical practices in the design process. Taking a CHAT framework, we analyse the multi-voiced nature of the design of hybrid spaces by considering the object-motives inherent in different historical practices (Engeström 1995). Having shown how recurrent tensions in design work can serve as catalysts for development, we suggest that the identification of these tensions are productive for the design work, as they may foster innovation in the design process.

References


