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Henriikka Vartiainen

Principles for Design – Oriented Pedagogy for Learning from and with Museum Objects

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ABSTRACT

The beginning of the twenty-first century has been described as a time of development for social innovations through which people use, share, and create knowledge in ways that differ fundamentally from those of previous eras. To enhance our students' chances of becoming active agents in their own lives and learning in settings far beyond classrooms, this design-based research aims to synthesize theoretical perspectives and empirical research in order to propose an approach to participatory learning that leverages the opportunities afforded by new technology, cultural environments, and communities, especially museums. The museum was selected as the exemplary context for the development of a research-based pedagogical model because previous research and practice have characterized school field trips to museums as missed educational opportunities.

The theoretical perspectives derived from the socio-cultural theory of learning and learning by collaborative designing serve as the framework for developing and exploring the pedagogical model for design-oriented learning in museums. The empirical research consists of three design experiments that present a continuum focusing on the iterative development of the model and examining different perspectives of it. In Study I, the aim was to examine what kind of learning systems emerged when three different student groups collaboratively designed their own museum visits with the support of a virtual design tool. Study II examined, through participant-led photography, the emergence of the object-oriented design process of pre-service teachers in museum settings. Study III focused on exploring how teachers from eight different European countries experienced the design-oriented pedagogical model and evaluated its usability.

What distinguishes the design-oriented approach from the traditional school field trip to a museum is that the learners themselves design the specific network of museum artifacts, tools, and other resources in terms of the shared design task and their own specific research questions. The results indicate that a technology-mediated design process for the museum visit enhances the creation of collaborative inquiry communities, but only to a limited extent, if the implementation of the activities in the museum does not adequately support participatory forms of learning. Careful consideration should be given to interactions during the museum visit with an emphasis on

changing of orientation from providing artifact-related knowledge towards drawing on the museum artifacts as a medium for communication and thinking in the pursuit of a shared object. In this way, museum professionals can better recognize the interests and needs of students from diverse backgrounds and how to guide them to use, connect, and organize the museum's artifacts and other resources in a way that supports the advancement of inquiry. The results of the study also emphasize the need for diverse personal, social, and professional tools to enhance thoughts and actions in the evolving process of designing, inquiring, and sharing outcomes. Furthermore, the students should be able to participate in the creation of newly made interpretations and combinations of resources with outcomes that are both personal and collective, and contribute to the extended learning community. However, it represents a profound change in the ways we perceive the role of students and learning contexts, and poses challenges for the teachers and educators to bring these pedagogical perspectives into existence, especially when the traditional school practices create various challenges and constraints. The developed research-based pedagogical model with elaborated design principles may help educators in different institutions to recognize current patterns and to facilitate connected learning across spaces and communities.

Keywords: Design-oriented pedagogy, participatory learning, collaborative designing, learning system, design-based research

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ABSTRAKTI

Tämän design-tutkimuksen tavoitteena on sekä teoriaan että empiiriseen tutkimukseen tukeutuen rakentaa näkökulmia osallistavaan oppimiseen, jossa yhdistyvät teknologian sekä kulttuuriympäristöjen, erityisesti museoiden, tarjoamat mahdollisuudet tukea oppijoitamme kasvamaan aktiivisiksi toimijoiksi elämässään ja oppimisessaan luokkahuoneen ulkopuolella. Museo valittiin kontekstiksi tutkimukseen perustuvan opetusmallin kehitystyölle erityisesti siksi, että aiempien tutkimusten ja käytännön kokemusten mukaan koululaisryhmien museovierailut ovat heikosti hyödynnetty oppimismahdollisuus.

Sosiokulttuurinen oppimisen teoria sekä yhteisöllisen suunnittelun periaatteet toimivat lähtökohtana design-suuntautuneen oppimisen edistämiselle ja tutkimiselle museokontekstissa. Tutkimuksen empiirinen osuus koostuu kolmesta design eksperimentistä, joissa pedagogista mallia kehitettiin iteratiivisesti eteenpäin tutkimalla sitä eri näkökulmista. Ensimmäisessä osatutkimuksessa tavoitteena oli selvittää millaisia oppimissysteemejä muodostuu kun kolme eri taustoista tulevaa oppijaryhmää suunnittelevat oman museovierailunsa tätä varten kehitetyn virtuaalisen suunnittelutyövälineen tuella. Toinen osatutkimus pyrki kuvaamaan osallistavan valokuvauksen kautta kohdekeskeisen oppimisprosessin muodostumista museovierailujen aikana opettajaopiskelijoiden tapauksessa. Kolmas osatutkimus pyrki puolestaan selvittämään miten kahdeksasta eri Euroopan maasta tulevat opettajat kokevat pedagogisen mallin ja arvioivat sen käytettävyyttä.

Design-suuntautunut lähestymistapa eroaa perinteisestä koululaisryhmän museovierailusta siten, että oppijat itse suunnittelevat museokohteiden, välineiden sekä muiden informaatioresussien muodostaman verkoston suhteessa yhteisölliseen suunnittelutehtävään sekä sitä tarkentaviin tutkimuskysymyksiin. Tutkimuksen tulokset osoittavat teknologian välittämän museovierailun suunnittelun tukevan osallistavaa oppimista, mutta vain rajoitetusti, mikäli toiminta museossa ei tue riittävässä määrin sen toteutumista. Tämä haastaa kiinnittämään erityistä huomioita vuorovaikutukseen museovierailun aikana sekä suuntaamaan toimintaa museokohteisiin liittyvän tiedon siirtämisestä artefaktien välittämiin mahdollisuuksiin ajattelun, toiminnan ja vuorovaikutuksen edistäjinä yhteisöllisessä suunnitteluprosessissa. Näin myös mu-

seoasiantuntijat voivat paremmin tunnistaa eri taustoista tulevien oppijoiden tarpeita ja kiinnostuksen kohteita sekä ohjata heitä hyödyntämään, yhdistämään ja organisoimaan museokohteita sekä muita resursseja oppimisprosessin syvenemistä tukevalla tavalla. Museokohteisiin liittyvien tutkimusten suunnittelussa, toteutuksessa sekä prosessin jakamisessa keskeisessä roolissa ovat myös erilaiset henkilökohtaiset, sosiaaliset sekä asiantuntijan toimintaa välittävät työvälineet. Osallistavaa oppimista voidaan myös vahvistaa sekä henkilökohtaisesta että kollektiivisesta näkökulmasta osallistamalla oppijat laajennetun oppijayhteisön toimintaan tuottamalla ja jakamalla sosiaalisessa mediassa suunnitteluprosessissa rakennettavia tulkintoja sekä yhdistelmiä museokohteista.

Design-suuntautunut pedagogiikka edustaa perusteellista muutosta oppijan roolissa ja oppimisen kontekstissa, asettaen monenlaisia haasteita opettajille niiden käytäntöön viemiseen. Tutkimuksessa kehitetyt tutkimusperustainen opetusmalli sekä oppimisen suunnitteluperiaatteet voivat kuitenkin tukea opettajia ja kasvattajia eri instituutioissa tunnistamaan nykykäytäntöjen rajoitteet sekä auttaa edistämään erilaisia yhteisöjä ja ympäristöjä yhdistävää osallistavaa oppimista.

Avainsanat: Design-suuntautunut pedagogiikka, osallistava oppiminen, yhteisöllinen suunnittelu, oppimissysteemi, design-tutkimus

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A fundamental assumption of my thesis is that learning and knowing is not located within the individual thinker, but emerges from joint efforts, and from fruitful interactions with other people. Indeed, this thesis is the result of collaboration among and co-development with various people, and it would have not been accomplished without their encouragement, support, and guidance.

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I began my research work as a research assistant on a very inspiring research project, the so-called Lusto Project, funded by the European social funds (Project No.86283), Forest Museum Lusto, Finnish Cultural Foundation and Jumppanen Foundation. This project introduced me to Dr. Petteri Vanninen, to whom I would like to express my great appreciation. He literally drew me out of the swamp, and has supported me, and collaborated with me in so many ways during these research-filled years. He was the one who actively built the bridges between different professional communities, and in that way, he opened up vital opportunities for learning and research. I also greatly appreciate the support received through the collaborative work undertaken with people in the Finnish Forest Museum Lusto and with the Finnish Forest Research Institute's researchers in Punkaharju during this project, and in our later collaborative activities. Furthermore, very special thanks go to Hanna Nygren and Suvi Pessala, who not only helped me with the data collection during this PhD work, but who were always so much fun to work with.

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Varpasen Asema, May 2014

Henriikka Vartiainen

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LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following four original publications, which are referred to in the text by their Roman numerals (Studies I-IV):

I Vartiainen, H. & Enkenberg, J. (2013). Learning from and with museum objects: design perspectives, environment, and emerging learning systems. *Educational Technology Research & Development, 61*(5), 841-862.[1]

II Vartiainen, H. & Enkenberg, J. (2014). Participant-led photography as a mediating tool in object-oriented learning in museum. *Visitor Studies, 17*(1), 66–88.[1]

III Vartiainen, H. & Enkenberg, J. (2013). Reflections of design-oriented pedagogy for sustainable learning: An international perspective. *Journal of Teacher Education for Sustainability, 15*(1), 43-53. [1]

IV Vartiainen, H., Liljeström, A., & Enkenberg, J. (2012). Design-oriented pedagogy for technology-enhanced learning to cross over the borders between formal and informal environments. *Journal of Universal Computer Science, 18*(15), 2097–2119.[2]

[1] The first and second author designed the study. The first author was responsible for the data collection, analysis and writing the manuscript. The second author provided theoretical and methodological guidance during the process.

[2] Article IV presents the co-developed pedagogical model and describes the continuum of the related design experiments, in which all the authors have been involved. The first and second authors were responsible authors for writing the manuscript. The first author wrote the manuscript otherwise, except paragraphs 3.1 and 3.3 in which the second author reports her own design experiments. The third author provided guidance during the writing process.

1 Introduction

At the beginning of the twenty-first century, we witnessed the emergence of the knowledge society, which is argued to have had profound effects on our health, educational, cultural, and financial institutions, and to have created an ever-increasing need for robust lifelong learning, innovation, and the knowledge and skills to solve the problems of the future (Scardamalia, Bransford, Kozma, & Quellmalz, 2011). According to Clinton, Jenkins, and McWilliams (2013), these rapid advancements in technological and sociocultural developments do not simply involve a shift in the technical infrastructure for communication, but shifts in the cultural logics and social practices that shape the ways in which we interact. These changes point us toward a more participatory culture, one in which people have an expanded capacity to communicate and circulate their ideas, and one in which networked communities can help to shape our collective agendas (Clinton et al., 2013). Fischer (2013) defines cultures of participation in which all people are provided with the means to participate actively in personally meaningful problems. Henry Jenkins, one of the first scholars to conceptualize the participatory culture, defines it as "a culture with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing one's creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices" (Jenkins, Clinton, Purushotma, Robison, & Weigel, 2008). Many of the practices of traditional folk cultures have these same features, with skills and knowledge passed from generation to generation through informal mentorship, mostly involving learning by making and creating within a shared social context (Clinton et al., 2013).

Lévy (2013) argues that contemporary social life generally means that we participate in many communities: as a member of a family, as a player in a sports team, as a practitioner of a discipline, or as a member of an online community. Each of these communities has a different cultural tradition, and is constituted through an autopoietic process of the construction, reproduction, and transformation of knowledge ecosystems. Their creative conversations accumulate, manage, and filter memories in which collective and personal identities define each other. Although face-to-face meetings remain essential for people to interact, more and more conversational interactions oriented toward collaborative learning are taking place online, for example, through social media. This new, ubiquitous digital environment, especially social media, has given rise to participatory knowledge cultures in which people work together to collectively classify, organize, construct, and evaluate information - a phenomenon that Lévy (2013) characterizes as the emergence of collective intelligence. If people are engaged in the collaborative production of a common memory, they share their expertise for the use of the community, and integrate the information received from

the collective efforts into their personal practice, and, thus, spread it across different communities (Lévy, 2013).

According to Scardamalia et al. (2011), technology blurs the line between in- and out-of-school contexts, and knowledge becomes a social product situated in open worlds, which calls for the need for environments that span educational contexts and support "community knowledge"; thus, group or "collective intelligence" will become increasingly important. According to Scardamalia et al. (2011), a knowledge-building environment, virtual or otherwise, is one that enhances collaborative efforts to create and continually improve ideas. It exploits the potential of collaborative-knowledge work by situating ideas in a communal workspace where members are continually contributing to, and enhancing the shared intellectual resources, so that at both the individual and group level, there is continual movement beyond current understanding and capacity. Emergence becomes a way of life and more personally satisfying than a life restricted to following known paths to known goals (Scardamalia et al., 2011).

Rheingold (2013) argues that these opportunities in our society challenge educators to develop participatory pedagogy, assisted by digital media and networked publics, which focuses on catalyzing, inspiring, nourishing, facilitating, and guiding learning that is essential to individual and collective life in the twenty-first century. Joseph and Czarnecki (2013) note that we should no longer merely focus on questions pertaining to digital media access, but, increasingly, to inequalities in access regarding opportunities for participating in cultures supporting the development of these new competencies and skills, such as working effectively and respectfully with diverse teams, exercising flexibility and having a willingness to make compromises to accomplish common goals, and assuming shared responsibility for collaborative efforts while valuing individual contributions. Similarly, the Assessment and Teaching of 21st Century Skills Project stresses the need for systemic educational reform, and has taken this approach for the required twenty-first century skills by referring to things such as communicating and collaborating to solve complex problems, adapting and innovating in response to new demands and changing circumstances, and using technology to create new knowledge and expand human capacity and productivity (Binkley, Erstad, Herman, Raizen, Ripley, & Rumble, 2011). According to Scardamalia et al. (2011), a deep understanding of domain knowledge can also be achieved through the exercise of twenty-first-century skills, and the result will be an enhanced understanding of the domain as well as advances in a broad range of twenty-first-century skills.

Participatory approaches to learning emphasize the importance of engaging students in authentic cultural activities and joint efforts to solve problems (Hakkarainen, Paavola, Kangas, & Seitamaa-Hakkarainen, 2013). The participation perspective for learning and education is focused not on delivering predigested information to individuals, but on providing opportunities and resources for learners to engage in social activities, to create shared understanding among diverse stakeholders, and to frame and solve authentic and personally meaningful problems (Fischer, 2013). It aims to enhance students into becoming active members who participate in culturally and personally relevant activities in which they appropriate the cultural resources

that enable them to participate in and contribute to the larger society (Wells, 2010). According to Jenkins et al. (2008), our goals should be to encourage youth to develop the skills, knowledge, ethical frameworks, and self-confidence needed to be full participants in contemporary culture. Similarly, Mizuko et al. (2013) argue in their new report that the function of schooling should be to prepare students for contributing to, and participating in social life, which includes economic activity, but also civil society, family, and community. By pursuing such connected learning, it can lead to broader communal and societal outcomes such as high-quality culture and knowledge products, civically-oriented collectives, and diverse and equitable pathways to opportunity (Mizuko et al., 2013).

The present study considers the participatory culture as exemplifying how new forms of collaboration and communication have important transformative potentials for more deeply engaging the learner in authentic forms of learning rather than more traditional, decontextualized classroom practices (Pea & Lindgren, 2008). This study focuses on the theoretical perspectives and practical developments for understanding, fostering, and supporting cultures of participation in education. The aim is to synthesize a body of theoretical perspectives and empirical research to propose an approach to learning that leverages the opportunities afforded by new technology, and by nature-based and cultural environments, especially museums. The museum was selected as an exemplifying context for the development of a new pedagogical model because previous research and practice have characterized fieldtrips to museums as "missed educational opportunities" that have failed to take advantage of the unique opportunities for learning afforded by such experiences (cf. DeWitt & Hohenstein, 2010).

Recognizing the uncertainty of how to educate our students to meet the above-mentioned changes and challenges and, on the other hand, how to bridge museum with school learning, a key theme across this thesis is the centrality of *design* as an approach to the development of participatory learning activities. By building on the perspectives of the sociocultural theory of learning, the present study focuses on the possibilities of extended learning environments and communities, physical artifacts, and tools as mediators of these practices. The thesis describes three design experiments that have been implemented to support the development processes of a design-oriented pedagogy (DOP), which is introduced in the fourth article. The thesis is organized into four parts. Part one provides the problem analysis that characterizes the needs that a design is intended to address. Part two describes the design principles derived from prior research and the educational literature, which provided a background and a starting point for designing and exploring the developed pedagogical model and related theoretical perspectives. Part three describes the methodological approaches that were selected, provides a description of the empirical data that were collected, and presents the three design experiments to address the development of the DOP. Finally, the fourth part presents the emerging conclusions and raises a series of recommendations to inform research and practitioners about the challenges and opportunities associated with design-oriented learning in museum settings.

2 Design Problem

According to Amiel and Reeves (2008), the goal of design-based research (DBR) is to build strong bridges between educational research and real-world problems. DBR emphasizes the iterative research process, which does not just evaluate an innovative product or intervention, but which systematically attempts to refine the innovation, and to guide similar research and development endeavors. The process begins from a problem analysis that characterizes the goals and the need that a design is intended to address (Edelson, 2002). Thus, the aim of the second chapter is to present a significant educational problem derived from the recent educational literature and review of the research related to museums, and the possibilities and challenges the museum offers in terms of learning for school groups.

2.1 LEARNING IN SCHOOLS

An international survey of teachers from 23 countries (Law, Pelgrum, & Plomp, 2008; Kozma, 2011) revealed that the three most common classroom pedagogical practices were having students fill out worksheets, working at the same pace and in the same sequence, and answering tests. Information and communication technology (ICT) was rarely used. Although the previously mentioned findings do not necessarily reflect the implemented practices at the local level in every school, there seems to be something that is unchangeable in education, such as the instructional method by which the educational organizations expect that the children and students will learn. In the famous book *Unschooling Society*, Ivan Illich (1971) defined a school as an "age-specific, teacher-related process requiring full-time attendance at an obligatory curriculum." Yet, in the age of information and networking, according to many researchers, most educational systems still operate much as they did in the seventies.

Wells (2008) argues that throughout most of the history of schooling, the goals of teaching have been to organize what is to be learned into appropriately sized and sequenced pieces, and to arrange optimal methods of delivery for ensuring that all students acquire the same set of knowledge. Individual students receive the same instruction from a teacher and compete with each other to score the highest grades on assignments and tests in which student success is largely assessed in terms of their ability to reproduce what they have been taught, often separated from any meaningful context. Little or no attention is given to students' diverse backgrounds, interests, and expertise, nor are they encouraged to show initiative and creativity in formulating questions and problems, or in attempting to solve problems in collaboration. Whereas schools are currently still training autonomous individuals, most activities outside the school are undertaken by groups of people whose members, with different areas of ex-

pertise, make different contributions to the tasks involved. Collaboration is a necessity for the successful achievement of the group's goals and competitive individualism is a hindrance rather than an asset (Wells, 2008). According to Scardamalia et al. (2011), such collaboration is characterized by emergent goals, which means that they are formed and modified in the course of pursuing them, and that they cannot be traced back to subskills or subgoals because they come about through self-organization.

Schooling has also been criticized suffering from problems of disconnected knowledge, separated from the context that makes it meaningful or from patterns of inquiry that experts use in knowledge construction (Perkins, 1986; Barab & Roth, 2006). Current education systems tend to anchor learning in formal environments, mostly in classrooms and from textbooks (National Education Technology Plan [NETP], 2010). While the overall goal of schooling is to prepare young people to be able to participate responsibly and productively in the wider society, the actual practices through which schooling takes place contradict with the practices beyond the school for which they are intended to provide preparation (Wells, 2011). The teachers and children stay in classrooms to talk about the rich and varied activities of life outside school, rather than actually participating in those activities (Lemke, 2002; Barab & Duffy, 2000). Brown, Collins, and Duguid (1989) argue that the practices of contemporary schooling often deny students the chance to engage with the relevant domain culture. Even though students are shown the tools of many academic cultures in the course of a school year, the pervasive culture that they observe, in which they participate, and which some enter into quite effectively, is the culture of school life itself (Brown, Collins, & Duguid, 1989). According to Greeno (1997), those practices may have value in school, but they preclude coherent development of many useful capabilities that may be even more valuable in students' lives beyond the classroom.

Furthermore, Rajala, Hilppö, Lipponen, and Kumpulainen (2013) argue that school learning offers little room for students' agency, including experiences that learners bring to school from other contexts, such as their homes, playgrounds, after-school clubs, libraries, science centers, and museums. The students come into school with knowledge and experience that is grounded in other communities and cultural resources, but the expertise gained elsewhere is often irrelevant in school, and vice versa (Eckert, Goldman, & Wenger, 1997). Roth and Lee (2006) claim that one of the typical features of teaching is that the students often do not know why they have been asked to learn something, except that good grades are important for their future. Thus, it seems that often the heterogeneous needs, interests, and backgrounds of the students are responded to with the homogenization of the content of teaching, and the standardization of the expected outcomes. The real concerns of the students, whether about drugs, sex, disease, food, clothing, or music are neglected, and no connection is made between them and the important scientific issues that underlie each of these legitimate student concerns (Lemke, 2002).

Mizuko et al. (2013) notes that the main drivers of participation are typically structured systems for instruction and assessment rather than those relating to intrinsic motivation or social belonging. The students do not exercise much choice over the objects of their tasks, and alternative ways of proceeding are neither recognized nor valued; instead, all students are asked to work alone on the same tasks at the same

time and to reach the same predetermined outcomes from a prescribed curriculum (Wells, 2008; Roth & Lee, 2006). When students primarily work alone, and individual knowledge and skills are assessed, one student's success highlights another student's failure (Mizuko et al., 2013). It also creates a very different motive for the students, involving very different cognitive practices, and they tend to engage in defensive forms of learning, rather than perceiving the expansion of their action possibilities with respect to truly interesting learning tasks and activities (Roth & Lee, 2006). According to Sahlberg (2010), one of the consequences is that students experience boredom rather than genuine interest during their schooling in many educational systems. Schools that do not promote the desire and need for learning, or the curiosity to know more, are not able to generate the type of productive learning that is required by the knowledge society. As long as schools continue to disconnect content from context, information from application, learning from participation, and knowledge from experience, they will sever the essential connection that facilitates the learner in creating meaningful relations in the world (Barab, Cherkes-Julkowski, Swenson, Garrett, Shaw, & Young, 1999). According to Kumpulainen and Lipponen (2012), there is a clear need for the development of pedagogical models, solutions, and activities that can bridge the gap between diverse learning contexts, and that can support learners' meaningful transitions and participation.

Although there seems to be uncertainty regarding how to educate our students to have successful lives in the future, there is also widespread recognition that the traditional ways in which schooling has been, and is organized is no longer a sustainable way through which to provide the knowledge and skills that students need for living in, and working in a knowledge-creating society (Thomas & Brown, 2011; Mizuko et al., 2013; NETP, 2010; Scardamalia, 2001; Scardamalia & Bereiter, 2006; Schank, 2011; Binkley et al., 2011). As we have entered the twenty-first century, it has become evident that our students are growing up in rapidly changing times, particularly because of the increasing pace of knowledge development and technological advances. These changes frequently emerge in educational debates, where a variety of beliefs and public opinions abound regarding what teaching for a knowledge society means, and how schools could best create the core qualities needed by students for our complex world (Sahlberg, 2010).

Several research groups have made significant contributions to educational thinking in their own pursuit of modern methods of learning, such as knowledge building (Scardamalia & Bereiter, 2006), progressive inquiry (Hakkarainen, 1998), project-based learning (Krajcik & Blumenfeld, 2006), and learning by designing (Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010). Although these approaches have their differences, a rough summary of what sets these approaches apart from the one described above is that they all seem to highlight shifting the focus in education from what teachers should teach, to collaborative learning, active participation, and being able to use different tools and technologies to create new knowledge for solving complex problems in diverse situations. While being inspired by these research-based approaches, the present study focuses on exploring how such perspectives on learning could be utilized in other educational settings, particularly museums, which have been said to have an important role in facilitating lifelong learning by providing a free-choice leaning environment (Hawkey, 2004).

2.2 LEARNING IN MUSEUMS

To clarify the difference between the nature of learning taking place in school environments and that in museums, learning in museums is often referred to as informal learning, non-formal learning, or out-of-school learning. Resnick (1987) highlighted the degree to which formal school contexts focus on the individual's performance, on symbolic thinking without the help of tools, and on teaching general skills and knowledge. Compared to out-of-school learning, where mental work is often socially shared, involves the use of tools, and is engaged in directly with objects, and in specific situations, schools seem to provide relatively limited opportunities for their learners. According to Gerber, Marek, and Cavallo (2001), the learning that takes place in schools is termed as *formal* due to the highly structured nature of the environment in which it occurs. They continue by clarifying how informal learning environments are less structured than the formal classroom settings, and may occur in institutions (e.g., museums, zoos), in organizations (e.g., Boy/Girl Scouts, Junior Achievement), or in everyday situations (e.g., watching television, taking piano lessons, working on hobbies, shopping for clothes). Such learning can be defined as the sum of activities that comprise the time that individuals are not in the formal classroom in the presence of a teacher (Gerber et al., 2001).

Jane Griffin (1998) describes museums as informal settings where learning is driven by curiosity, where visitors can choose their experiences, and where learning may be fragmentary, unstructured, and collaborative. With such learning, personal ownership is a fundamental component (Griffin, 1998). According to Paris and Hapgood (2002), museum environments are generally characterized as learning based on artifacts and experiences rather than text, which is one of the key distinctions between formal school and non-school environments. In schools, the students are also more often directed by others as they learn, whereas museum visitors are often self-directed, and choose their own routes, pace, level of engagement, and social group as they explore the exhibits (Paris & Hapgood, 2002). According to Rowe (2002), part of what makes the museum a unique learning environment is the multiple ways of interacting and organizing social activity around and with museum artifacts. The nature of the activity and the meaning of the museum artifacts are up for negotiation by people in ways that may be explicitly or implicitly prohibited in other learning settings, such as in schools (Rowe, 2002).

According to Eshach (2007), formal learning usually takes place in institutions (e.g., schools or universities), and is typically characterized by its highly structured and sequential nature, involving extrinsic motivation and evaluation of the learning. Informal learning is portrayed as participation in out-of-school settings, in situations that occur in everyday life, such as within the family circle, the neighborhood, and so on. To a large extent, this type of learning is characterized as unstructured, spontaneous, voluntary, and usually learner-led. Informal learning is not evaluated and motivation is mainly intrinsic. However, Eshach (2007) defines learning that takes place in institutions out of school, such as museums, as non-formal learning. Non-formal learning is shown to be supportive, structured, and is usually pre-arranged. The sources of motivation are more intrinsic than in formal learning and are usually

voluntary. It may also be guided or teacher-led, but is usually not evaluated (Eshach, 2007).

Consequently, this distinction about learning entails much more than just organization or physical settings, involving a complex set of individual and social aspects of situated learning. Another conceptualization is offered by Bell, Lewenstein, Shouse, and Feder (2009), who defined museums as *designed settings*. By designed settings, they refer to the intended communicative and pedagogical goals of designers and educators, and to the leaner's personal choice in these settings. The learning in designed settings is characterized as highly participant structured, where the visitors may freely choose what to see and explore, with no or limited direct facilitation from institutional actors. According to Bell et al. (2009), museums and other designed spaces such as science centers and environmental centers offer unique possibilities to pursue and develop science interests with real-world phenomena, to engage in science inquiry, and in the negotiation of meaning. Ideally, these environments enable students to connect with their own interests, provide an interactive space for learning, and encourage in-depth exploration of current or relevant topics on demand (Bell et al., 2009).

It is well established that science centers with interactive exhibits and objects can promote learning in very attractive ways (Bell et al., 2009; Gutwill & Allen, 2012), but the situation is rather contradictory in more conventional museums. Although the research in such museum settings is rather limited, research provides some evidence that school trips to such places can result in learning science content, in positive emotional responses to science and the natural world, in engagement in exploration and interaction, and in reflecting on science (Bell et al., 2009). Such experiences may also afford valuable opportunities for students' active agency and more dialogic teacher–student interactions (Kumpulainen & Lipponen, 2012; DeWitt & Hohenstein, 2010).

Despite recent attention being placed on the learning potential of museums, studies of school-group fieldtrips have shown that school students are not always afforded the opportunity to exploit all of these possibilities (Griffin, 2004; Tal & Morag, 2007; Rennie & Johnston, 2004). According to Kisiel (2005a, 2005b), during a school fieldtrip, however, choices are typically made for the students, and students may have little control over the visit. In his study on the motivations that comprise teachers' agendas when leading student fieldtrips to science museums or similar sites, he found that during the school trip, the student's experience during a museum fieldtrip typically lacks many aspects of "free choice," and that the student visitors become a secondary audience. Motivations involve the teacher's justification as to why the students should go to the museum, such as breaking up the classroom routine with a fun experience, a connection to the curriculum, or making a decision based not on what the needs of the students are, but on the requirements of the school setting (Kisiel, 2005a, 2005b). Likewise, Griffin and Symington (1997) found similar results with their study on the strategies used by class teachers before, during, and following excursions to museums. According to Griffin and Symington (1997), very little preparation was involved for these excursions and what was done was often merely organizational. The follow-up mainly consisted of collecting and marking the worksheets filled in by the students. The results of the study indicate that when the teachers brought classes

to a museum, they mainly used structural and task-oriented teaching practices, and showed little recognition of the different learning environment or the learning opportunities that museums could offer. The outcomes of their investigation also suggested that most visits were poorly linked with topics being studied at school and that the teachers had no clear idea of how to use the museum as a learning resource (Griffin & Symington, 1997).

These arguments are in line with the study by Cox-Petersen, Marsh, Kisiel, and Melber (2003), who investigated docent-led guided tours at a museum of natural history by observing approximately 30 visiting school groups. They found that a typical visit to a museum was a structured, docent-directed, and lecture-oriented tour in which students and teachers moved together as a whole group. During these tours, the docents guided the students throughout the exhibit, provided different facts related to the objects, and the tour content seldom connected to what students were learning in school or to their prior knowledge or interests. The students played a passive role in these tours and the interaction among docents, students, and exhibit artifacts was limited (Cox-Petersen et al., 2003).

Moreover, Tal and Morag (2007) had a similar result in their 3-year study of school visits to natural history museums in Israel. Their observations of 42 guided visits indicate that the main visitation pattern consisted of guide-centered and task-oriented activity, in which the main, common feature at all the museums was a long introductory talk that consisted of about half of the overall duration of the museum visit. During these introductions, the guides used PowerPoint slide presentations, experimental demonstrations and models, and artifacts that they showed to, and sometimes allowed the students to examine. Some of the museums also used worksheets and one museum used small-group inquiry on rare occasions. Frequently, the visits included combinations of these activities and were filled with overly complex scientific jargon. Although the museums provided a variety of learning activities, the students' main activity was answering guided questions. Tal and Morag (2007) also undertook a closer analysis of these questions and found that the guides mainly asked lower-cognitive-level types of questions that required yes or no answers, or the recalling of previous, simple knowledge. If students wanted to address a question, the guide moved on and ignored them. Less than 5% of all of the questions challenged the students to think or share meaningful experiences with their classmates. In general, the students had limited opportunities to engage actively with objects or with their peers, and they had little time to freely explore the exhibit (Tal & Morag, 2007).

A more recent study by Stavrova and Urhahne (2010) examined instructional methods in organized guided tours that best support students' cognitive and affective learning as well as how students' motivational and emotional states influence their achievement. They organized two different versions of a guided tour that varied in terms of the degree of support for students' active involvement, group work, and the variety of general activities offered during the tour. Their results indicate that both tour versions led to an increase in student understanding of the visit topic to nearly the same extent, but the version enhancing students' active participation, group work, and including a larger variety of activities generated more positive attitudes. Based on their results, they conclude that the frequently mentioned recommendations in

the museum research literature, such as encouraging students' active participation or working together in groups, can significantly improve students' motivational and emotional states during the visit, and are successful in promoting student understanding. The characteristics of the non-formal learning locations, such as their rich environment, give museums a chance to engage students in a way that schools never can. Yet, this is only possible if the museum educators, teachers, and developers do not restrict themselves to classroom-like instruction within these settings (Stavrova & Urhahne, 2010).

Although the Finnish educational system is highly praised globally (Valtonen et al., 2013) and consistently successful and renowned in international comparative studies on educational systems, such as the Programme for International Student Assessment (Organisation for Economic Co-operation and Development, 2010), very little research has been conducted about the use of out-of school environments in Finnish schools. However, our recent background studies (Liljeström, Vartiainen, Vanninen, Enkenberg, & Pöllänen, 2013c; Vartiainen, Liljeström, Enkenberg, Vanninen, & Pöllänen, 2013) concerning Finnish pre-service teachers experiences in extended learning environments and learning communities indicated that, during their school history, the students have had very few experiences of learning in diverse physical environments or social and technological environments outside of the classroom. The analysis of the Finnish pre-service student teachers' experiences of fieldtrips during their years in school indicated that fieldtrips offer limited occasions for students' agency, and the main drivers of participation were joining predetermined guided tours rather than actually engaging in the activities of expert communities. Furthermore, the pre- and post-visit activities for bridging learning in and out of schools were rather uncommon, and there were no pursuits for creating outcomes to be shared beyond the classrooms. The results of these studies also indicate a rather narrow use of tools and technologies during the out-of-school activities.

All these studies emphasize the pressing need for both museum and school staff to review their practice, and to apply more student-centered approaches that allow active learning and a variety of opportunities to explore and learn in a personalized and contextualized manner (Tal & Morag, 2007; Cox-Petersen et al., 2003; Kisiel, 2005a, 2005b; Griffin & Symington, 1997). They also highlight the clear need to provide teachers with viable alternatives to their current ways of conducting school excursions (Griffin & Symington, 1997). Teacher-training institutions and museums also need to consider how to enthuse teachers' interest in museum exhibits, because their personal interest has a significant, long-term effect on children's attitudes (Jarvis & Pell, 2005). Consequently, for the creation of learning environments that extend beyond traditional contexts and practices, the educators need to work across professional boundaries, which requires both collaborative networks and the ability to work with other professions (Lipponen & Kumpulainen, 2011).

Indeed, in order to deepen students' learning and create bridges between school-based and museum learning, research suggests that pre-visit preparation together with follow-up activities in school are needed to advance the learning potential of a school fieldtrip (Bamberger & Tal, 2009; Bell et al., 2009; Griffin & Symington, 1997). It is necessary to promote collaborative, inquiry-based learning during fieldtrips, where

students can generate and pursue their own research questions, experience and explore things they find interesting, and where they are provided with the tools to do so (DeWitt & Storksdieck, 2008; Gutwill & Allen, 2012; Bamberger & Tal, 2009; Griffin, 1998). Instead of simply mirroring existing forms of school teaching in the museums, these field trips should make more use of the rich learning environment with a range of flexible learning opportunities to widen these traditional horizons, thereby better addressing twenty-first-century learner interests and lifelong learning needs.

3 Design Perspectives

To meet the above-mentioned challenges, this study aims to enhance participatory activities situated in schools, museums, and technological environments by co-developing a model for design-oriented learning. The aim of this chapter is to describe the theoretical framework and design principles derived from prior research and the educational literature, which provided a background and a starting point for designing and exploring the developed model.

This framework is comprised of three parts. The first part begins by presenting insights into the sociocultural approach to learning, focusing on the perspectives that have become the key building blocks in the development of the pedagogical model. The second part discusses learning through collaborative design, which is considered as a promising instructional perspective with which to bring the theories emphasizing participation, mediating artifacts, and tools into fertile interaction. Part three extends these perspectives by discussing the mediation of artifacts through technology.

3.1 SOCIOCULTURAL INSIGHTS OF LEARNING

A sociocultural approach to learning means participating in cultural practices (Wenger, 1998) in which the learning activities are bound to the context in which they take place (Sfard, 1998) and to the people, tools, and artifacts that mediated them (Schoultz, Säljö & Wyndhamn, 2001). Schauble, Leinhardt, and Martin (1997) suggest that the sociocultural theory is a promising, guiding theoretical framework for museum learning, because it can turn attention toward the activities that are supported in museums, and toward the role of mediating tools and artifacts in learning. They continue that such perspectives on learning are particularly fruitful for educators, teachers, and museum professionals who are interested not only in understanding learning, but also in promoting productive forms of it (Schauble, Leinhardt, & Martin, 1997).

3.1.1 Vygotsky's basic mediated-action triangle

The sociocultural approach originally derives from the culture-historical framework of Lev Vygotsky (1978). At the time when psychologists were intent on developing simple explanations of human development, Vygotsky's central idea was that our actions and thinking are mediated by cultural means (artifacts and tools), and by other people such as a peers, teachers, and experts during specific social activities. Figure 1 represents Vygotsky's basic mediated-action triangle (adopted from Cole & Engeström, 1993).

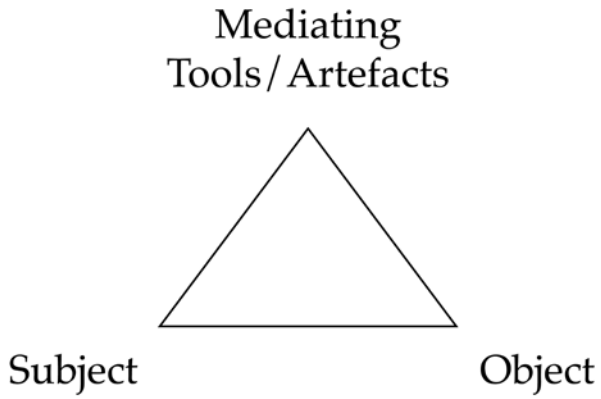

Figure 1. Mediated action (Cole & Engeström, 1993).

The triangle depicts the relationship between the subject (the actor or actors participating in the activity), the object of the activity, and the tools and artifacts as mediational means that actors use for acting on the object. In contrast to the behaviorist model of action based on stimulus and response (S–R), Vygotsky outlined how human contact with the world is indirect and mediated by physical or psychological tools (Wertsch, 2007). Vygotsky (1981) made a distinction between the functions of psychological and material tools:

> The most essential feature distinguishing the psychological tool from the technical tool, is that it directs the mind and behaviour whereas the technical tool, which is also inserted as an intermediate link between human activity and the external object, is directed toward producing one or other set of changes in the object itself (p. 140).

Vygotsky outlined that all tool-mediated activity is inherently social (Wells, 2007), and that artifacts and tools both shape the possibilities for thought and action, and, in turn, are shaped by the subject who uses them (Daniels, Cole, & Wertsch, 2007). For Vygotsky, the mediational function for these tools was not only in assisting performance but in the chance in subjects the mental structures (Edwards, 2007). Wertsch (2007) explains that the mediated action develops and involves a dynamic transition. The first encounter with cultural artifacts and tools emerges without a full understanding of their meanings and functional roles. What then follows is a process of coming to understand their meaning and functional role with increasing levels of sophistication. From this perspective, the general goal of instruction involves providing children with cultural tools and social settings that support increasing levels of expertise in using these tools flexibly and fluently (Wertsch, 2007).

For Vygotsky, participation was a crucial feature of learning. He emphasized the essential role played by the experienced others, who can support and expand the learning of the child, and pass on the skills and knowledge from generation to generation through this mentorship (Kozulin, Gindis, Ageyev, & Miller, 2003). As a key

concept with which to explain the role of collaboration and social mediation, Vygotsky (1978) introduced the concept of the zone of proximal development (ZPD) that he defines as: "The distance between the actual developmental level as determined by independent problem solving and the level of potential development determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 78). Through the support of joint activities with more experienced others, we can transcend our solo limitations, and achieve things that, on our own, would have been beyond our grasp (Wells & Claxton, 2002).

3.1.2 Subject, object, and mediational means

Rather than being seen as an individual mental process, learning from the perspective of the sociocultural approach is considered as a collaborative process that takes place in groups, communities, and networks (Hakkarainen, 2010). According to Wenger (1998), we all belong to communities of practice, whether that is at work, school, home, or in our civic and leisure interests. His basic argument is that learning involves a deepening process of participation and a gradual movement from peripheral to central participation in the activity in question. From the sociocultural perspective, the subject of learning is a community rather than an individual (Hakkarainen et al., 2013), and there can be different forms of human mediation. For example, Rogoff (1995) proposes three aspects of subject participation, including apprenticeship, guided participation, and participatory appropriation. The metaphor of apprenticeship is related to community activity, involving active individuals participating with others in a culturally organized activity that has, as part of its purpose, the development of mature participation in the activity by the less experienced members. Guided participation refers to the processes and systems of involvement between people as they communicate and coordinate their efforts while participating in a culturally valued activity. Participatory appropriation refers to a process of becoming, rather than acquisition, in which individuals change through their involvement in one or another activity, in the process becoming prepared for subsequent participation in related activities (Rogoff, 1995). However, Barab et al. (1999) note that these groundbreaking works by Rogoff (1995) and Wenger (1998) that focus our attention on the participation were carried out through an anthropological perspective, with an examination of communities of practice in everyday, out-of-school society. Yet, we are still in our infancy with respect to understanding how we can promote these perspectives within the walls of schools (Barab et al., 1999).

Hakkarainen (2010) argues that in order to be considered a community of learning, a group of people needs to have an object of activity. Related to the needs or desires of organizing mediated activities, the literature drawn from researchers with a special interest in cultural-historical activity theory (CHAT) reflects plenty of discussion about the object or the object of activity. Leontiev (1978) emphasizes that all activity is object-oriented, and that behind the object, there is always a need or a desire to which the activity answers. The object of the activity can be considered the ultimate reason behind various behaviors of individuals, groups, or organizations. It can be defined as "the sense-maker," which gives meaning to, and determines the values of various entities and phenomena (Kaptelin & Miettinen, 2005). According to Hyysalo (2005), the objects and motives of activity can also be collective, including a number of

personal motives, which become integrated into a shared object of activity. The objects are, in this sense, constructed by actors, and have histories, and built-in affordances (Engeström & Blackler, 2005). Miettinen and Virkkunen (2005) elaborate on the object discussion by arguing that objects are not always things with fixed qualities, but can be open-ended projections oriented to something that does not yet exist, or to what we do not yet know for sure. Thus, they are also generators of new conceptions and solutions, and can be considered as a central source of innovation and reorientation in societal practices (Miettinen & Virkkunen, 2005). Nicolopoulou and Cole (2010) explain that the CHAT perspective places culture at the center of human sense-making activities, emphasizing the influences of social interaction in a jointly constructed activity, and the role of mediating artifacts in this process.

According to Muukkonen-van der Meer (2011), such a systemic approach to learning may also provide a fruitful perspective on learning and the design of educational settings that are applicable beyond the framework of activity theory (see also Vuojärvi, 2013). For example, drawing on the sociocultural theory and the CHAT, Paavola, Engeström, and Hakkarainen (2012) propose a difference in the "object" as a social motive of activity by approaching the notion as concrete objects that people develop collaboratively. These objects being developed could be epistemic entities (research problems, working theories, or pieces of knowledge), designed artifacts (prototypes, concrete products), joint events (e.g., exhibitions), or pursuits of societal challenges (Hakkarainen, 2010). According to Paavola, Engeström, & Hakkarainen (2012), in trialogical approach to learning, the focus is on those ways in which people collaboratively produce artifacts, and they relate practices to distributed means, and focus on designing pedagogical settings so that the artifacts produced and the practices that are developed are re-usable outside the exact pedagogical situation (e.g., one course). Thus, such a shared object is concrete, but at the same time it is something in the process of being developed and modified iteratively (Paavola, Engeström, & Hakkarainen, 2012).

Moreover, mediating thought artifacts is one of the founding premises of the Russian cultural-historical school, as they considered that material objects were modified by human beings as a means of regulating their interactions with the world and with each other (Cole & Engeström, 2007; Jarvis & Pell, 2005). Cole (1996) argues that artifacts are simultaneously ideal (conceptual) and material:

> … they are manufactured in the process of goal directed human actions. They are ideal in that their material form has been shaped by their participation in the interactions of which they were previously a part and which they mediate in the present. Defined in this manner, the properties of artifacts apply with equal force whether one is considering language/speech or the more usually noted forms of artifacts such as tables and knives, which constitute material culture. What differentiates the word "table" from an actual table is the relative prominence of their material and ideal aspects and the kinds of coordinations they afford. No word exists apart from its material instantiation (as a configuration of sound waves, hand movements, writing, or neuronal activity), whereas every table embodies an order imposed by thinking human beings. (p. 117)

Over time, a range of artifacts has been produced that has modified how people learn in various situated practices. Some of these artifacts have had a very general impact, while others have been more local, affecting the way in which a particular practice is organized (Säljö, 2003). According to McDonald, Le, Higgins, and Podmore (2005), artifacts are simultaneously a record of the past and an agent for the transmission of their meaning and use in the future, and they play an essential role in ensuring the continuity of human culture. Cole (1995) argues that artifacts constitute a unique medium of human life, the medium we know as human culture. They do not exist in isolation, but are related to each other and the social lives of the human beings that they mediate in a variety of ways (Cole, 1995). Mäkitalo, Jakobsson, and Säljö (2009) express how a physical object is embedded in diverse social practices through the following example: If we take a simple object such as an orange, the satisfied consumer may speak of its delicious taste and its juiciness, the dietician will speak of it in terms of nutritional value and richness in vitamin C, and the artist may attend to it in terms of its color, shape, and texture in the context of what is to be a still life. Consequently, the same artifact can function in various ways in different contexts, and the distinction is dependent on the context and form of the activity that is mediated (Wells, 2007).

According to Schoultz, Säljö, and Wyndhamn (2001), another distinctive characteristic within the sociocultural perspective is the emphasis placed on the relevance of the tools that are available as resources to enhance our thoughts and actions. Our ability to carry out an activity effectively resides not only in our individual knowledge or abilities to work and collaborate; it is also distributed across the artifacts and tools that are to hand and the affordances provided by the environment (Wells & Claxton, 2002). Säljö (2010) argues that rather than looking for human competences solely in our minds or bodies, our knowledge is expressed in our abilities to use external tools, and to integrate them into the flow of our doings, whether these are intellectual, physical, or mixed. To be a competent participant in many activities involves the mastery of a range of tools and instruments (Säljö, 2010). Brown, Collins, and Duguid (1989) argue that tools can only be fully understood through their use, and using them entails both changing the user's view of the world, and adopting the belief system of the culture in which they are used. The situations and settings for use arise out of the context of activities of each community that uses the tool, framed by the way members of that community see the world (Brown, Collins, & Duguid, 1989). Similarly, John-Steiner and Mahn (1996) argue that tools are not invented by individuals in isolation; instead, they are the products of sociocultural evolution to which people have access by being actively engaged in the practices of their communities. Wertsch, del Rio, and Alvarez (1995) point out that tools as well as artifacts involved in mediation play an essential role in shaping action, but they do not determine or cause action in some kind of static, mechanistic way. They can have their impact only when people use them (Wertsch, del Rio, & Alvarez, 1995), and they can be used in various ways, and can be embedded in diverse social practices, often involving multiple tools and tool-mediated actions (Francis, 2007).

3.2 LEARNING BY COLLABORATIVE DESIGNING

As emphasized by the sociocultural framework, the educational function of museums results not only from the artifacts, but is deeply affected by the activities around them. If we want to develop these interactions and create new kinds of learning spaces that people can change, design, experiment with, and use in a variety of ways, we have to intervene in the current practices in a purposeful way to change the relationships between people and resources (Loi & Dillon, 2006). Thus, this study aims to apply the instructional perspectives of learning by collaborative designing (LCD).

According to Roth (2001), *design* is a heterogeneous process that integrates, associates, and weaves together diverse tools, materials, artifacts, people, and agencies. He argues that designing artifacts is a social process and a core human activity. According to Perkins (1986), design refers to the human endeavor of shaping an object to purpose. The process of designing typically requires people who come from different backgrounds and with different types of expertise to work together (Bucciarelli, 2001), and involves the re-combination of multiple resources and tools for a specific purpose (Francis, 2007). Alternatively, Balsamo (2010) defines design as an inherently multidisciplinary practice of cultural reproduction that provides opportunities for people to participate in activities of cultural creation. Dillon and Howe (2003) approach design as narrative, which has negotiated meaning, and emphasize the importance of context to understanding design.

Fischer (2013) argues that collaborative design and social creativity are necessities for the most interesting and important problems in today's world. Mäkitalo, Jakobsson, and Säljö (2009) notes that we are now held accountable not just for what is in one particular artifact, text, or even in large numbers of sources; the summarizing of what is known is not enough. Rather, it is our ability to make insightful and productive use of the collective resources in locally relevant ways that is of interest (Mäkitalo, Jakobsson, & Säljö, 2009). Rather than just emphasizing "what is already known," the "design" metaphor emphasizes the creative element in the interpretive activities of learners that go beyond giving back what is already there (Säljö, 2010). To contribute in the twenty-first-century means not only content-based knowledge, but also those situated practices where we need to apply knowledge in a way that is meaningful (Salen, Torres, Wolozin, Rufo-Tepper, & Shapiro, 2011). Knowledge, from this perspective, is the practice of change rather than a body of facts, concepts, or rules that can be transferred from one situation to another (cf. Matusov, Julien, Lacasa, & Alburquerque Candela, 2007).

Empirical studies indicate that learning by designing can engage students in the sustained effort of building knowledge and can be applied in different educational contexts (e.g. Enkenberg, 1993, Enkenberg, 2001; Harel, 1991; Kodoner, 2002; Roth, 1998; Hennessy & Murphy, 1999; Lahti, 2008; Pöllänen & Vartiainen, 2013). These approaches are largely based on design activities that emphasize active collaboration, employ real-life contexts, and seek to develop learning tasks and projects that demand inquiry (Pöllänen & Vartiainen, 2013). In this study, the instructional perspectives on LCD have been anchored especially to the educational thinking of Pirita Seitamaa-Hakkarainen and her colleagues, who have used sociocultural approaches in order to develop and study instructional models and perspectives on learning by collaborative

designing (Seitamaa-Hakkarainen, Kangas, Raunio, & Hakkarainen, 2012; Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010; Lahti, 2008; Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004; Kangas, Seitamaa-Hakkarainen, & Hakkarainen, 2011). Although LCD as an instructional perspective has not been utilized within museum-education research studies, it can be considered as a promising instructional perspective to bring the theories emphasizing participation, mediating artifacts, and tools into fertile interaction in learning practices.

Hmelo, Holton, and Kolodner (2000) argue that design activities can be an excellent way to help students acquire a deeper and more systemic understanding of complex problems. When learning by designing, the students need to describe, predict, or explain some phenomena, which requires them to discuss and invent objects and their relations to each other, as well as to consider functions and causal behaviors of the components. According to Roth (2001), designing refers to the process of arranging elements to form systems, including the design of experiments involving the construction of procedures, instruments, and material configurations. Roth (1998) also argues that many abstract principles, which are difficult to learn from textbooks, become easier to understand and more engaging when approached through design process.

Furthermore, complex design objects can be addressed from different perspectives (Hakkarainen et al., 2013) and they intentionally bring into play multiple disciplines, multiple ways of working, and different habits of the mind, and community (Lombardi, 2007). They also provide students with opportunities to design and perform inquiries (Krajcik & Blumenfeld, 2006), and to choose different kinds of perspectives and paths with which to engage in inquiry (Liljeström, Enkenberg, & Pöllänen, 2013a). According to Roth and Lee (2006), the expansion of action possibilities with respect to truly interesting learning tasks is also deeply connected to the perceived ownership of learning.

Hakkarainen et al. (2013) argue that in LCD, a group of students needs to have a shared object of activity. The object (e.g., symbolic-material artifacts, such as questions and theories, or practices) are brought within the LCD approach by engaging the students in the collaborative pursuit of varying complex and multifaceted problems that often come from outside of educational institutions, and, thereby, break the epistemic boundaries of school learning (Hakkarainen et al., 2013). The students solve the ill-defined, complex, authentic, and challenging design tasks (Lahti, Seitamaa-Hakkarainen, & Hakkarainen, 2004; Pöllänen & Vartiainen, 2013) that arise from the phenomena of the real world and this provides the students with opportunities to make connections to their own interests, and to practices that represent the work of expert communities (Krajcik & Blumenfeld, 2006). Kangas et al. (2011) notes that design problems guide the design process, but are likely to significantly transform when the process advances through successive, iterative stages. The stages cannot be completely foreseen, as the process requires going through evolving and iterative efforts to "translate" conceptual ideas to materially embodied artifacts. Likewise, Pöllänen and Vartiainen (2013) argue that collaborative design projects require sustained engagement in an iterative (i.e., spiral and cyclic) design process to apply, develop, and test new solutions. According to Hakkarainen et al., (2013), novel knowledge emerges through the interaction between conceptualization and the practical exploration involved in design and inquiry.

From the subject perspective, LCD emphasizes interaction within and between peers or teams, between students and the teacher, and external domain experts (Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010). It emphasizes the creation process in which students actively communicate, share their expertise, make joint decisions, and work together in solving emerging problems, as well as the process of evaluating and modifying their outcomes through dialogue and action (Hennessy & Murphy, 1999). According to Liljeström, Enkenberg, and Pöllänen (2013a), it also recognizes and values the variety and diversity of the existing expertise of the students, and emphasizes sharing ideas, thoughts, and skills, which are appropriated for the whole collective. Seitamaa-Hakkarainen et al. (2012) note that the students also need experiences of working with domain experts, who can mediate their tacit knowledge, practices, and goals when solving problems, and working with knowledge, as well as their values and identities. Breaking boundaries between school and cultural communities can also provide opportunities for appropriating novel roles and developing one's agency (Hakkarainen et al., 2013).

According to Murphy and Hennessy (2001), in design settings, students share a task around real artifacts, which have a fundamental role in mediating the collaborative learning processes. Balsamo (2010) argues that the meanings that are created in designing are mediated through the construction of objects that can be material as well as digital, representational as well as gestural, and theoretical as well as physical. Through this externalization, the ideas of the students become visible and improvable, enabling their collaborative advancement (Seitamaa-Hakkarainen et al., 2012). Seitamaa-Hakkarainen et al. (2010) argue that designing cannot be reduced to a mere play on ideas; in order to understand and improve the ideas in question, they have to be given a material form by means of practical exploration, prototyping, and manufacturing. The students have to, in parallel, be both "minds on" (working with ideas) and "hands on" (implementing or prototyping ideas by creating materially embodied artifacts), and they need to embody their thoughts and intentions in shareable cultural artifacts. Seitamaa-Hakkarainen et al. (2010) suggest that such knowledge artifacts should be considered to be conceptual (questions, theories, ideas) and material artifacts (drawings, graphics [including those that are digitally embodied], prototypes, experimental equipment, and concrete items and products). According to Roth (2001), produced artifacts are external (rather than mental) models, which are negotiated and designed in public rather than in private mental spaces. Thus, design as a context for learning is quite different from the epistemological positions typically found in classrooms, because students have a lot of flexibility to define and set their own goals; thus, they are able to design their activity in pursuit of evolutionary processes with emergent outcomes (Roth, 2001).

3.3 MEDIATION OF ARTIFACTS THROUGH TECHNOLOGY

Although people can develop artifacts and practices jointly and systematically without any technologically advanced tools (Hakkarainen et al., 2013), technology may provide varied types of mediation for learning; that is, epistemic mediation related to creating, transforming, working with, and linking knowledge artifacts; pragmatic mediation related to planning, organizing and coordinating tasks and work processes; social

mediation for building and fostering social networks and relations; and reflective mediation to support making visible, reflecting on, and transforming the practices (Muukkonen-van der Meer, 2011; Paavola, Engeström, & Hakkarainen, 2012). The new technology may support the LCD process by assisting in externalizing, recording, and sharing organizing all aspects and stages of the design process, and may provide novel tools that are needed for transforming material entities into digital artifacts (Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010).

In the present study, the particular interest is on using technology as a medium for enhancing design-oriented learning from and with museum artifacts. Development of digital technologies has made it possible to represent a museum and its artifacts in several ways and from different perspectives and the learners have access to a huge number of museum objects surrounded by contextual and tailored information over the Internet (Frost, 2002; Hawkey, 2004; Paris & Hapgood, 2002). Kress (2003) points out that the change form print-based media to the new ICTs have made it easy to use a multiplicity of modes, and, in particular, the mode of images—still or moving—as well as other modes such as sounds. With print-based technology, the production of written text was made easy, whereas images were relatively rare due to the monetary cost. With the new technology, these costs are minimal compared to the print-based technology, and the communication world around us is moving toward a preference for images in many domains, and into the domain of everyday communication. Importantly, it offers the potential to realize meaning in different modes (Kress, 2003). According to Hennessy (2011), *modes* are organized sets of semiotic resources for representation and communication, which include images, gestures, writing, speech, gazes, and interaction with artifacts. Multimodal digital artefacts may be represented in various forms or employ a combination of them, such as texts, drawings, diagrams, still photographs, multimedia presentations, animations, simulations and models of dynamic processes, interactive diagrams, maps, concept maps, databases, graphs, tables, hyperlinked web pages, audio and video files, and mathematical representations. Giaccardi and Fitzcarrald (2004) propose that the new technological opportunities challenge us to reconsider the current function and representation of museums in order for them to be a meaningful place for learning. Problems remain because museums seem to concentrate only on building a digital copy of the physical museum, instead of enhancing and deepening learning from museum artifacts (Prosser & Eddisford, 2004). To meet these challenges, this study attempts to apply the concept of the *learning object* to augment the meditational potential of museum artifacts.

After the popularization of the Internet, the concept of learning objects has received remarkable attention and enthusiasm in educational settings, and in the way in which educational materials are designed, developed, and delivered to those who wish to learn (e.g., Churchill, 2005; Jonassen & Churchill, 2004; Wiley, 2000; Wiley, 2007). A variety of guiding metaphors to describe learning objects and their appropriate use have been proposed—including terms such as LEGOs (Hodgins, 2002) and bricks and mortar (Wiley 2007)—emphasizing the idea of offering content in re-usable units that can be used in various learning situations. The most cited definition of learning objects is proposed by the Institute of Electrical and Electronics Engineers' (IEEE, 2005) Learning Technology Standards Committee: "Learning Objects are defined here

as any entity, digital or non-digital, which can be used, re-used or referenced during technology supported learning." According to Wiley (2007), the reaction against this extremely broad definition has been very strong, and dozens of alterative definitions have been proposed, making it difficult to find shared definitions for the learning object. In practice, however, the early enthusiasm has waned, and this is due, at least in part, to a neglect of the pedagogy, and an emphasis on the technical aspects of interoperability and reusability (Harden, Gessner, Gunni, Issenberg, & Pringle, 2011). Thus, in this study, insights from Vygotsky and later elaborations of his ideas have served as a framework for developing the conceptualization of learning objects representing museum artifacts.

4 Design-Research Method

According to Rowe (2002), most museum research has focused on the output of school-like knowledge (i.e., recall of discrete facts) as the most viable measure of learning. Similarly, Hauser, Noschka-Roos, Reussner, and Zahn (2009) point out that the educational research in museums has traditionally focused on visitor and evaluation studies, particularly in the area of educational exhibition evaluation. According to Hauser et al. (2009), the focus in such studies is on analyzing visitor reactions to a specific exhibition rather than on a deeper understanding of the learning processes that are occurring. They argue that although evaluation studies may deliver useful instructions for developing interpretive materials, they are often bound to specific exhibitions, rarely allowing for generalizations and theory improvements in the field. Similarly, Schauble, Leinhardt, and Martin (1997) consider such an approach as problematic, because the evaluation studies are usually not grounded in the theory of learning or motivated by the theory development. In addition, it is not clear how the results obtained through basic visitor research really apply to practice (Hauser et al., 2009).

Rowe (2002) argues that understanding the role of the artifact in mediating people's museum experiences requires taking a research perspective that accounts for the active, distributed meaning making that people do in museums. To be able to understand how visitors' learning can be facilitated at museums according to a sociocultural perspective, Schauble, Leinhardt, and Martin (1997) stressed the need for new approaches. They recommend that museum professionals and learning researchers work together to address these challenges by pursuing the development of knowledge on museum learning together that will result in outcomes that will build on the theory. They argue that museum studies should focus on exploring the experience, knowledge, and interest that visitors bring to museums, what kind of activities and pathways they engage in during their visits, and the means by which museums contribute to their evolving ways of knowing and responding to the world. The key question is then how these learning activities that occur in museums can best be encouraged, fostered, and deepened so that they afford increasing levels of opportunity for future growth (Schauble, Leinhardt, & Martin, 1997).

Schauble, Leinhardt, and Martin (1997) were also one of the first research groups to suggest the possibilities of DBR for advancing theory, and, at the same time, to translate research into practice in museum settings. According to them, the idea of conducting theory-driven research on prototypes that will eventually be revised based on empirical research is a promising approach to bring theory and research into a sustainable relationship with authentic practical problems. Therefore, to address such complex problems in educational practice for which no clear guidelines for solutions are available, this study also considers design as a tool to advance understanding, and sees DBR as a method to integrate the design process with scientific research.

The aim of this study is to design and explore a theory-driven and research-based pedagogical model for artifact-mediated learning in museums. Drawing on the sociocultural perspective on learning, the present study focused on the exploration of the systemic, context-bound nature of learning, which is mediated by people, physical and conceptual artifacts, and tools. As Paavola, Engeström, and Hakkarainen (2010) point out, theories and theory-driven design principles are typically quite abstract and general, and do not give very much guidance in terms of designing the actual pedagogical practices or tools supporting these practices. Thus, the thesis consists of three empirical studies that form a continuum from focusing on different perspectives of the theory-driven learning system and the related development of a pedagogical model.

4.1 PRAGMATISM AS A PHILOSOPHICAL UNDERPINNING

Wertsch et al. (1995) outline that that underlying assumption of sociocultural research is that humans do not have access to the word directly, but indirectly, and mediately. This applies both with regard to how humans obtain information about the world and how they act on it, which are usually viewed as being deeply intertwined. A fundamental issue to be addressed in analyzing action is how several moments in its organization are involved in a complex, dynamic system. The role of various influences may vary from one context to another, and at various stages of development, and they cannot be defined in isolation. It also reflects the pervasive assumption that meditational means or cultural tools play an essential role in sociocultural research, and provide the link between the concrete actions carried out by people and the cultural, institutional, and historical settings (Wertsch, 1995: Wertsch, del Rio & Alvarez, 1995). Wertsch et al. (1995) argue that sociocultural studies should be involved in changing and not just investigating human action and the cultural, institutional, and histological settings in which it occurs.

As educational researchers engage in research that influences practice, they are increasingly choosing to incorporate design into their research activities (Edelson, 2002). According to Edelson (2002), in the traditional theory-testing paradigm, design and research are separate processes that happen sequentially. With such an approach, design takes place first as the implementation of the theory, followed by the evaluation-oriented research. However, design can also play a significant role in the development of theories, not just in their evaluation. Challenging or innovative design requires extensive investigation, experimentation, and iterative refinement to acquire a substantial, new understanding. Thus, an important characteristic of such DBR is that it eliminates the boundary between design and research, and recognizes design as an important approach to research in its own right (Edelson, 2002). Hence, the goal of the researchers, educators, and designers moves beyond offering explanations of, and onto designing interventions for learning (Barab & Kirshner, 2001). According to Juuti and Lavonen (2006), research about education has an intellectual objective to understand teaching and learning better, and research on education has a pragmatic objective to improve teaching and learning praxis. Such a performative nature of learning and knowing implies a focus on what is new, relevant, and pro-

ductive, rather than merely on what is true in an absolute sense, and echoes some of the arguments made by, and epistemological positions held by pragmatists (Säljö, 2003; Confrey, 2006). There are, of course, many variations within pragmatism, but according to Johnson and Onwuegbuzie, (2004) the classical pragmatists (e.g., Charles Sanders Peirce, William James, and John Dewey) shared an interest in examining practical consequences and empirical findings to help in understanding the import of philosophical positions, and, importantly, to help in deciding which action to take next as one attempts to better understand real-world phenomena.

According to Johnson and Onwuegbuzie (2004), pragmatism offers a useful middle position philosophically and methodologically, as it offers a practical and outcome-oriented method of inquiry that is based on action and leads, and iteratively, to further action, and the elimination of doubt; and it offers a method for selecting methodological mixes that can help researchers better answer many of their research questions. Johnson and Onwuegbuzie (2004) suggest that classical pragmatism's most general and important characteristics are, for example, that theories are viewed instrumentally (they become true and they are true to different degrees based on how well they currently work; workability is judged especially on the criteria of predictability and applicability), that classical pragmatism prefers action to philosophizing and endorses practical theory (theory that informs effective practice), it perceives current truth, meaning, and knowledge as tentative and as changing over time, and suggests that our thinking follows a dynamic process of belief, doubt, inquiry, modified belief, new doubt, and new inquiry, where the researcher and research community constantly tries to improve upon past understandings in a way that fits and works in the world in which they operate. Such pragmatic methodology is able to break away from the rigid structures of traditional educational research, and enables the use of multiple approaches and mixed-methods research in answering research questions (Johnson & Onwuegbuzie, 2004).

According to Morgan (2007), the pragmatic approach relies on a version of abductive reasoning that moves back and forth between theory-driven, deductive mode and a data-driven, inductive mode. One of the most common uses of abduction in pragmatic reasoning is to further a process of inquiry that evaluates the results of prior inductions through their ability to predict the workability of future lines of activity. The emphasis is on processes of communication and shared meaning that are central to any pragmatic approach, as we need to achieve a sufficient degree of mutual understanding with not only the people who participate in our research, but also with the colleagues who read and review the products of our research. Thus, the pragmatist emphasis on creating knowledge through lines of action points to the kinds of "joint actions" or "projects" that different people or groups can accomplish together. With a pragmatic approach, an important question is the extent to which we can take the things that we learn in one specific setting and make the most appropriate use of that knowledge under other circumstances (Morgan, 2007).

Paavola and Hakkarainen (2008) approach pragmatism from the point of view of mediation, underlining the interactivity of people and cultural means. They suggest that abductive reasoning should not be seen only as individually and mentally oriented problem solving, but should be considered as a socially and physically dis-

tributed process. Many of the problem-solving processes of today require people to collaboratively develop and create new ideas, artifacts, and practices, including the tools and resources with which the problem is solved. Thus, the creation of knowledge is embedded in the interaction with the environment, as well as in community-based conceptual and cultural artifacts and practices, and their systematic development. By building on the knowledge-creation metaphor of learning, they present the trialogical approach where the role of both knowledge artifacts and practices are emphasized. In the epistemology of knowledge, rather than justification of knowledge, attention should be paid to the creation of new knowledge, and how the knowledge is intertwined within such issues as community, activities, and practices, as well as within the physical and conceptual artifacts (Paavola & Hakkarainen, 2008).

4.2 DESIGN-BASED RESEARCH

The DBR movement originate from the pioneering works of Allan Collins (1992) and Ann Brown (1992), who introduced the term design experiment as they began to turn their attention to the learning processes and iterative interventions within real-world contexts. Since the 1990s, the need for a research approach that addresses complex problems has led many respected educational researchers to promote this rather new research methodology for educational research (Anderson & Shattuck, 2012). Efforts by several interdisciplinary groups over the past decade to conduct design research at the level of educational systems have shown the significant promise of the strategy of engaging researchers and practitioners in a model of collaborative, iterative, and systematic research and development (Penuel, Fishman, Cheng, & Sabelli, 2011).

DBR methods focus on designing and exploring the designed innovations that embody specific theoretical insights about learning, and reflect a commitment to understanding the relationships among theory, designed artifacts, and practice (Design-Based Research Collective, 2003). By grounding in real-world problems, DBR can provide a lens for understanding how theoretical claims about learning can be transformed to foster learning in educational settings (Design-Based Research Collective, 2003). According to Cobb, Confrey, diSessa, Lehrer, and Shauble (2003), DBR aims at understanding the learning ecology conceived as a complex, interacting system involving multiple elements of different types and levels. Elements of a learning ecology typically include the learning tasks or problems that students pursue, the kinds of discourse that are encouraged, the norms of participation that are established, the tools and related material means provided, and the practical means by which the teachers can orchestrate relations among these elements. They highlight the complexity of the educational system by emphasizing that designed contexts are conceptualized as interacting systems rather than as either a collection of activities or a list of separate factors that influence learning (Cobb et al., 2003). Additionally, Bielaczyc (2013) points out that "through investigating contexts developed by design, the central aim is to contribute to a multilayered understanding of learning and teaching; of agents, actions, and interactions; and of systems" (p. 264). Thus, such a research focus and method seem to be in line with the learning theories that take into account the social and cultural context within which learning is situated.

Bielaczyc (2013) notes that educational interventions can be advanced without developing a deep understanding of how and why things work. However, the design research methodology seeks to determine and to provide a means of constructing robust theories of critical elements of an intervention, and how their combinations make for effective learning environments (Bielaczyc, 2013). In DBR, the emphasis is placed on an iterative research process that does not just evaluate the designed product or intervention, but systematically attempts to refine the innovation while also producing design principles that can guide similar research and development endeavors (Amiel & Reeves, 2008). Typically, the research process is cyclical in nature; involving analysis, design, evaluation, and revision activities that are iterated until a satisfying balance between ideals ('the intended') and realization has been achieved (Plomp, 2009). Reeves (2006) illustrates the DBR process as follows (figure 2):

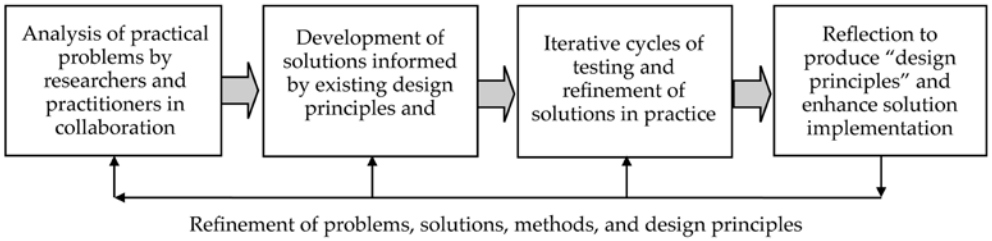

Figure 2. Design-based research approach (Reeves, 2006).

According to Amiel and Reeves (2008), the problem analysis in DBR typically involves negotiation with practitioners, who are seen as a valuable partner in establishing the research task and identifying problems that merit investigation. In other words, in the analysis and exploration phase of DBR, the problem is explored intensively, not solely from an academic perspective, but also from the perspective of the people who deal with the problem on a day-to-day basis (Herrington & Reeves, 2011). Consequently, the DBR often involves a close relationship between researchers and teachers or implementers, blurring the "objective" researcher–participant distinction (Hoadley, 2004). Involving different participants in the process of design enables them to bring their differing expertise into producing and analyzing the design (Barab & Squire, 2004). According to Plomp (2009), such collaboration increases the chance that the designed intervention will indeed become practical and relevant for the educational context, which increases the probability of a successful implementation. The participation of practitioners should also be seen as an important form of professional development and they may develop an awareness of how the research may contribute to improving their professional context (Plomp, 2009).

According to Herrington and Reeves (2011), after the articulation of the problems that drive the investigation, the next phase focuses on designing the learning solution or intervention that will potentially provide a solution to the problem. Such designing of the draft principles is informed by the relevant theory that can guide critical and creative thinking, as well as previous research and existing design principles that

may have addressed a similar or parallel problem (Herrington & Reeves, 2011). The next phase involves the implementation and evaluation cycles, in which data are collected systematically in order to re-define the problems, possible solutions, and the principles that might best address them. In such an iterative process, new designs are created and implemented, producing a continuous cycle of design–reflection–design. The outcomes of DBR are a set of new design principles that will undergo a series of testing and refinement cycles (Amiel & Reeves, 2008).

4.2.1 Case-study approach

Muukkonen-van der Meer (2011) suggests that whereas the research approach of DBR can describe how the progressive refinement of pedagogical design and theory development takes place in iterations, case studies or multiple case-study research design can be used to explain how the data collection and data analysis have been arranged in each sub-study. According to Laru (2012), case studies can serve the purposes for the iterative development of instructional design in DBR in two ways: 1) outcomes are used to guide revisions to the instructional designs and practical arrangements themselves, but also inform the selection of tools and technologies; and 2) outcomes can also serve to help researchers to understand the learning processes and how these were affected by the tools, the instructional designs, and the arrangements themselves.

According to Yin (2009), the distinctive need for case studies arises out of a desire to study and understand complex social phenomena. Yin (2009) describes case studies as "the preferred method when "how" or "why" questions are being asked, when the researcher has little control over events, and when the focus is on a contemporary phenomenon within a real-life context" (p. 2). Typically, the boundaries of the phenomenon and the context are not clearly evident, the case-study inquiry copes with situations in which there will be many more variables of interest than data points, and as one result relies on multiple sources of evidence, it benefits from the prior development of theoretical propositions to guide data collection and analysis. Yin (2009) makes a distinction between a single case design and multiple case designs, suggesting that case studies can be holistic, including a single unit of analysis, or embedded, including multiple units of analysis. Typically, multiple case design consists of theory development, implementation of the individual case studies following replication logic, and then, on drawing "cross-case" conclusions (Yin, 2009). Although such an approach differs from the one used in DBR, including the continuous refinement of problems, solutions, methods, and design principles, Yin (2009) points out that case-study designs can also be modified by new information or a discovery during data collection. Cobb et al. (2003) argue that design-based researchers can undertake analysis during the experiment in progress to support the learning of the participants, and to design a new cycle in the iterative process, and then, they can conduct retrospective analyses of the extensive, longitudinal data sets generated during an experiment to place the design experiment in a broader theoretical context. In a sense, the present study can be characterized as a multiple case study with an embedded perspective of the unit of analysis in which three design experiments were implemented and published as case studies, and the summary of the thesis aims to synthesize cross-case conclusions and discuss them within the theoretical framework.

4.2.2 Participants of the study

The present thesis and all the studies presented in it are also outcomes of multidisciplinary collaboration. The first and the second studies involved a design team consisting of educational researchers, museum staff, forest researchers, and a technological designer, who began to develop the virtual design environment and instructional model collaboratively to enhance the learning of the school groups arriving at the Finnish Forest Museum. The third study is based on the efforts of a consortium consisting of 12 partners from 8 different countries, who combine their efforts to facilitate teaching and learning of sustainable development.

As our broader goals with all the three experiments was to design novel model for crossing over the borders between formal, non-formal, and informal environments and communities, it was necessary to investigate the models with various target groups and with varying situational conditions. The participants of the studies reported in this thesis where from primary school (study I), technical college (study I), and teacher education (study I & II), and the third iteration was implemented with an international group of forestry experts and teachers. Study I was part of the Lusto Project, study II was conducted as part of a pre-service teachers' course, and study III was part of Case Forest pedagogy toward a sustainable development -project.

4.2.3 Data collection and analysis

In general, in each study, the data were collected from multiple sources. The data collection was done by the researchers (e.g., video and audio recordings, interviews, questionnaire) and produced by the participants (e.g., photographs, research plans, learning objects, final reports). All the sub-studies are mainly based on qualitative methods, but the quantitative method was used in the preliminary research when we were comparing two instructional models to determine which way to proceed with the design (article IV). To some extent, the dissertation can be described as research based on a mixed-methods approach using both quantitative and qualitative research methods (Johnson & Onwuegbuzie, 2004). However, instead of combining quantitative and qualitative methods, the focus was more on collecting multiple qualitative data in the sub-studies, and using different qualitative analytical methods and units of analysis. According to Bryman (2012), an epistemological position in qualitative research is described as interpretivist, in which the stress is on understanding the social world through an examination of the interpretation of that world by its participants. He described the ontological position of qualitative research as constructionist, which implies that social properties are outcomes of the interactions between individuals, rather than phenomena that are out there and separated from those involved in their construction (Bryman, 2012). Thus, this suggests, for example, that a physical artifact in a museum can exist without human apprehension, but it becomes meaningful when it is embedded in human action and in the interaction with people, who may experience the same artifact in different ways. However, as discussed above, the main focus of the present thesis is not to understand how people make meaning of museum artifact, but it has a pragmatic objective to improve teaching and learning praxis around these artifacts. These theoretical assumptions also lead to a rejection of the individual subject as the unit of analysis in favor of a situated or mediated activity or event as the unit of analysis (Sawyer, 2002).

Chi (1997) argues that the main benefit of qualitative research is that it can provide a rich and deep understanding of a situation; however, it also suffers from subjective interpretation and nonreplicability. According to Sawyer (2013), qualitative methods are particularly valuable in situations that are characterized by collaborative emergence, in which the activity has an unpredictable outcome, rather than a scripted outcome. Qualitative methods were selected due to the complex nature of the research object and were used to create rich descriptions of these implementation cases, to analyze selected aspects relating to the specific cases and contexts, and for the further development of the model.

The analytical framework applied in the sub-studies is primarily a qualitative content analysis. According to Mayring (2000), qualitative content analysis can be applied in all sorts of recorded communication (transcripts of interviews, discourses, protocols of observations, video tapes, documents, etc.) and he defines it as an approach of methodological controlled analysis of texts within their context of communication, following content analytic rules models, without rash quantification. Bryman (2012) defines it as an approach to documents that emphasizes the role of the researcher in the construction of the meaning of and in texts. Furthermore, there is an emphasis on allowing categories to emerge out of data and on recognizing the significance for understanding the meaning of the context in which an item being analyzed (and the categories derived from it) appeared (p. 714). Chi (1997), whose ideas have been applied to many forms of qualitative data, discusses verbal analysis, which she defines as "a methodology for quantifying the subjective or qualitative coding of the contents of verbal utterances" (p. 273).

As the goals of the analyses reported in this thesis were to be able to understand the emerging learning systems supported by DOP, which involves the subjects, and objects, and considers the role mediating the artifacts and the use of tools, in all of the sub-studies, the pedagogical design was examined using multiple data sources. Verbal data included various representations of spoken and written articulations, including such things as transcripts of small-group dialogues (studies I, II, III), oral presentations (III), and students' and teachers' written work (I, III), which were mediated by museum artifacts or representations of them (studies I, II), and the use of tools such as a virtual design environment (study I), digital cameras (studies I, II), and the pedagogical model (study III). In general, the analytical processes for the verbal data required viewing through the recordings, defining a more specific research interest, and selecting sections of the data that were relevant to the research questions, and which were transcribed for further analysis.

In general, different phases of DOP were examined in the sub-studies; the first study paid particular interest to the data collected from the design phase of the museum visit, the second study was more focused on analyzing the activities in the museum, and the third focused on analyzing teachers' reflections on the pedagogy after the process. Once those choices were determined, the transcribed material was read through several times in order to determine what constituted a unit of analysis for coding. As Chi (1997) points out, the defining cut can occur at many points, revealing units of varying grain sizes, such as a sentence, an idea, or an episode (such as an event, or a specific activity).

In the sub-studies of the dissertation, content analysis was used with qualitative data both in an inductive and deductive way. For the inductive approach, the coding categories were not predetermined, but rather emerged through interaction with the data, such as the content of the students' and teachers' discussions (studies I, II, & III) and the content of the student photographs (studies I & II). Deductive content analysis was used when the structure of analysis was operationalized based on previous research, such as when categorizing the participation in the activities and the students' study questions (study I), and when deriving the analysis categories from the structured questions of the country reports (study III). In studies I and II, the qualitative analysis also included a combination of quantitative methods (frequency counts). Publication IV differs from the other publications because it includes a summary of four design experiments and a synthesis of the development of the DOP. Table 1 summarizes the data collection and data analysis in the present thesis, which is further elaborated in the overview of each experiment.

Table 1. Studies, pedagogical models, participants, research questions, analysis methods, and original publications.

Study	Pedagogical model	Subjects	Research questions	Data source	Data analysis
I	Learning from and with learning objects produced by expert	Primary school group (*N* = 17) Technical college students (*N* = 7) Teacher-education student group (*N* = 14)	What kind of learning systems emerged when learners from different educational backgrounds worked in the learning environment?	Video recordings, Interviews, Photographs, Written and visual materials produced by the learners Questionnaire*	Qualitative, inductive, and deductive content analysis
II	Learning by designing learning objects	Teacher-education student group (*N* = 20)	What kind of photographic data did the students collect for their object-oriented design process? How did the tool-enhanced and object-oriented collaborative design process emerge in the museum?	Video and audio recordings, Photographs. Questionnaire*	Qualitative , inductive content analysis Statistical analysis (descriptive analysis, variance analysis [non- parametric]*
III	Learning by designing learning objects	International teacher group (*N* = 221)	What could be the problems, possibilities, and possible users of the design-oriented pedagogy according to the participating teachers? How did the teachers of the project envision the possibilities of the design-oriented pedagogy?	Video recordings, Interviews, Written and visual materials produced by the participants, Questionnaire	Qualitative content analysis, inductive and deductive content analysis

* Article IV presents the questionnaire designed to measure the teacher-education students' engagement and experiences in relation to the two pedagogical models.

The present thesis is part of our 8-year pursuit of iterative DBR, in which the model of DOP has been tested and validated in several design experiments with learners' groups of different backgrounds. Consequently, the present study is also related to design experiments other than those reported in the present thesis and the advances they enabled. The continuum of the experiments is descried in article IV, and elaborated on in publications by Liljeström et al. (2013a; 2013b; Liljeström, Vartiainen & Enkenberg, 2009, see Appendix 1).

5 An Overview of the Development of the Design in Empirical Studies

According to Wang and Hannafin (2005), the initial design plan derived from theory is usually insufficiently detailed, so that designers need to make iterative cycles of analysis, design, and development to further improve its ability to address the problem. In such a process, the methods also vary during different phases as new needs and issues emerge, and the focus of the research evolves (Wang & Hannafin, 2005). Thus, once a theory-driven solution for the problem is designed, the next phase in this DBR encompassed the implementation and evaluation of it in practice. When reporting on a design experiment that involves multiple phases, researchers usually describe their designs and corresponding results in a phase-by-phase manner (Zhang, Scardamalia, Reeve, & Messina, 2009). To avoid repeating the published articles, this chapter focuses mainly on the elaboration and evolution of the design during these three empirical experiments, aiming to consider the role of the subject, objects, and mediating means, and the link between them.

5.1 DEVELOPMENT OF THE DESIGN IN EXPERIMENT 1

Vartiainen, H., & Enkenberg, J. (2013). Learning from and with museum objects: Design perspectives, environment, and emerging learning systems. *Educational Technology Research & Development, 61*(5), 841–862.

5.1.1 Aims and development of the design

The first design experiment (study I) aimed at responding to the previously discussed problems in school-group museum visits by enhancing the use of museum artifacts and inquiry tools in learning through developing a new kind of virtual environment. At first, the development process involved several discussions to identify what issues museum practitioners faced when working with school students, and was guided by the review of the theory and research literature, and the group, involving educational researchers, museum staff, forest researchers, and a technological designer, began to develop the virtual design environment and instructional model collaboratively to enhance the learning of the school groups arriving at the Finnish Forest Museum Lusto. Study 1 was also the first attempt to reconceptualize learning objects as a part of a design-oriented learning system (figure 3).

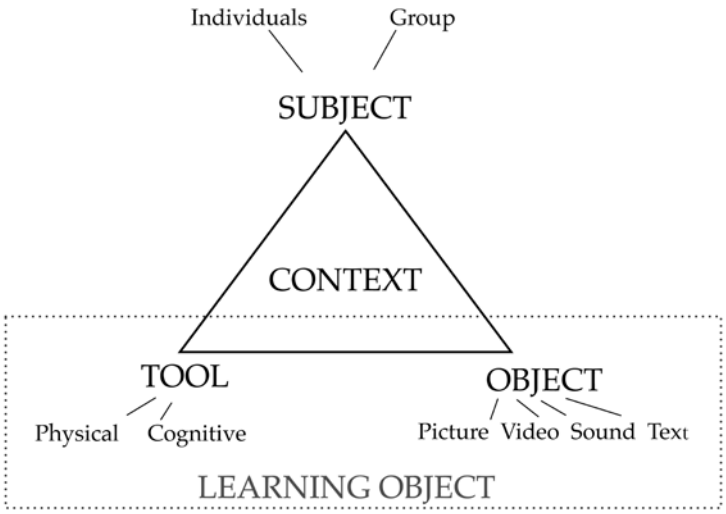

Figure 3. First conceptual model of the design-oriented learning system.

Drawing on the perspectives derived from sociocultural theory, the conceptual model consisted of three central factors: subject, object, and tool. When constructing digital representations of museum artifact and nature objects for the virtual design environment, the idea was to represent the museum artifacts and nature objects in several media (e.g., video clip, audio, drawing, picture, or textual information) and integrate them closely with the most relevant physical and cognitive tools. Thus, the museum visitors were modeled as subjects who applied the negotiation of meaning and the object for learning supported by representations of physical artifacts and objects, and related tools, which augment physical and cognitive activity.

These theoretical insights were embedded in the design processes of the virtual design tool to design the research trip to the museum environment. The learning task (cf. the object in the LCD activities) was brought within the design tool by encouraging the students to articulate the research questions collaboratively, and to choose the objects, methods, and tools for learning from the museum, or to research the forest park around it in a free-choice manner. Instead of a one-subject or domain-specific approach, the designed environment aimed to scaffold the negotiations of meaning by challenging learners to approach the forest-related issues from different perspectives and expert cultures (in our case economics, engineering, anthropology, or biology).

In the opening page, the environment was introduced, and orientation activities were shown to the learners to support the articulation of the driving questions of the whole class (shared object for learning). In the opening page, there were digital stories about learning processes other groups had undergone, short descriptions about expert cultures, articles from newspapers about topical phenomenon related to forests and their management, a description of the tools that could be useful in researching museum artifact and nature objects, and a glossary (forestry and learning sciences). Design resources and tools were offered on the flip side. A capture of the pages (originally in Finnish) is presented in figures 4 and 5 below.

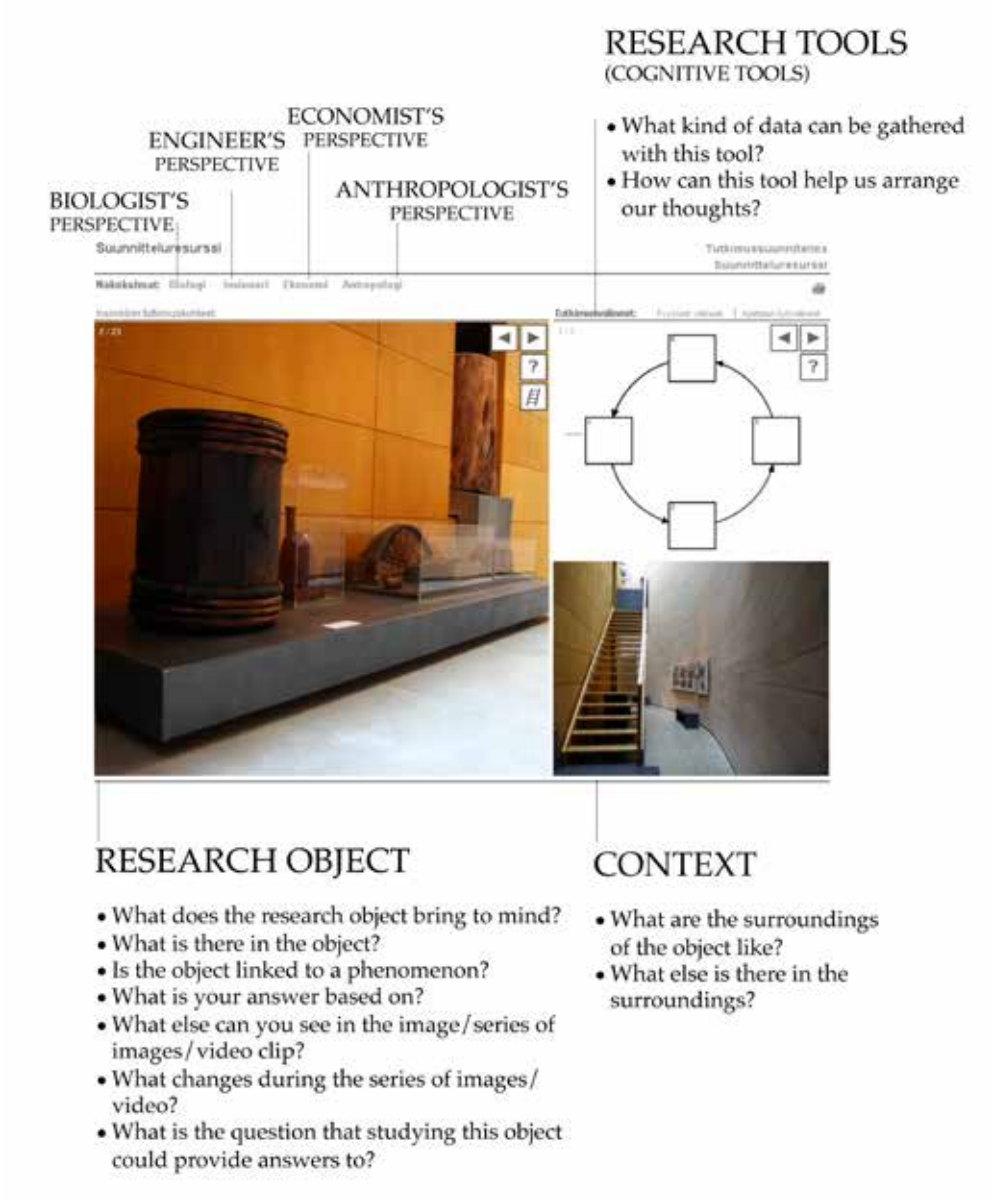

Figure 4. Museum learning object.

Figure 5. Forest learning object.

It was possible to perceive artifact, nature objects and tools in different media (textual, pictorial, and/or video). To construct a shared design object and inquiry plans for answering the question, the design resources allowed the learners to choose the expert's perspective from which they wanted to study freely, to scan the learning objects, and the built-in tools and contexts. On the same page, the learners could open a template for an inquiry plan and start work with it. For the inquiry plan, the group of learners were

expected briefly to describe what the study artifact or the nature object they wanted to study was, and which research question they wanted to examine, and in what ways. The inquiry plans were posted by email before the visit to the museum guide so that he or she could prepare for the coming challenges, expectations, and questions (figure 6).

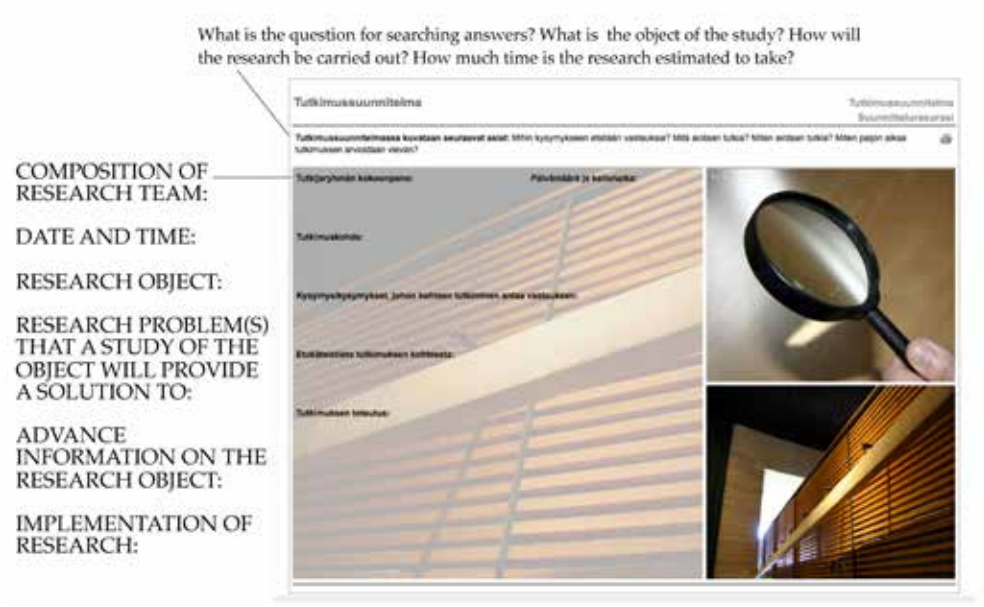

Figure 6. Research plan.

The study builds on the model of using existing learning objects, in which the instructional process has been separated into the consequent phases of orientation, designing an inquiry plan, inquiry, and generalization and sharing (figure 7).

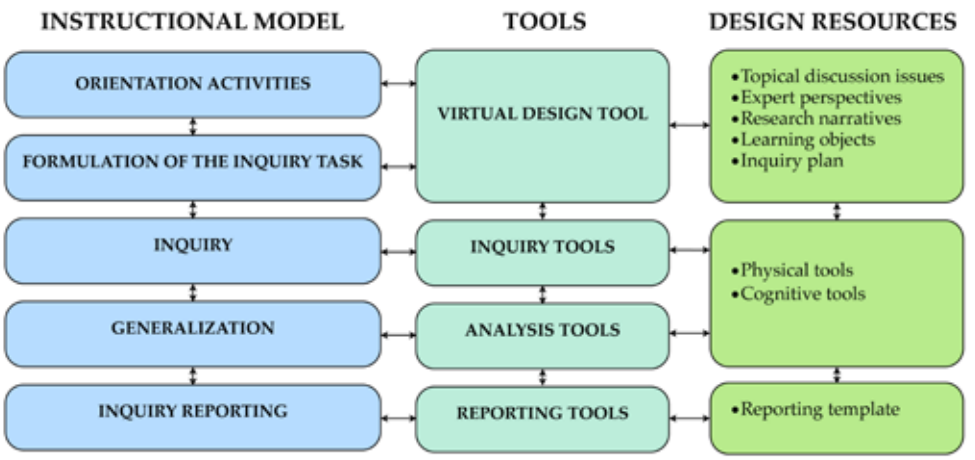

Figure 7. The instructional model for learning through learning objects.

In practice, the design process was planned to begin at school, where the students, together with their teachers, were expected to go through the orientation activities to prepare the project by formulating their shared object for learning, and the related inquiry questions of the small groups. After the orientation activities, the students began, in collaborative groups, to scan the design resources and choose interesting objects to study with the related tools. Finally, they formulated an inquiry plan with a research task and activities to be implemented in the museum or forest research park. The design phase was followed by implementation of the learning project. In this phase, students traveled to the museum or nature/forest environment to study the chosen objects and collect inquiry data for developing answers to their research questions. The final phase was to be to organize and analyze the collected material, share the findings, and reflect on the project. This was supposed to happen mostly in the school.

5.1.2 Cycles of testing the design

As Bielaczyc (2013) points out, if design research involving technology-based tools is aiming to impact educational settings, the design process must be extended beyond the tool itself to encompass a broader range of factors such as the social structures. The empirical study of the design tool and afforded learning system sought to explore what kind of learning systems emerged as three different student groups collaboratively designed their visits to the Finnish Forest Museum based on their own interests and afforded resources in the learning environment. The validation of the first version of the developed learning environment took place during the years 2007 and 2008 by three different learner-study groups, including a multi-age primary class with 17 students (case 1), 7 technical college students (case 2), and 14 pre-service teachers (case 3). All of these groups designed and implemented their learning project involving the Forest Museum, and a nearby research park (case 1 and 2). The data analysis focused on (1) the preconceptions of the students about forests and museums; (2) research questions that the students constructed (the nature of knowledge-seeking questions); (3) the content of the students' discussions during the design phase (mediation of the negotiation of meaning); (4) the learning process that emerged (the modes of participation); and (5) what kinds of photographic data the teacher-education students collected to answer their own research questions.

5.1.3 Reflections on the design

According to Wertsch, del Rio, and Alvarez (1995), when planning or analyzing new forms of mediation, the focus is typically on how these new means may overcome some perceived problem or restrictions in existing forms of mediated action. Any form of mediation involves some form of limitation, and even if new tools can recognize the limitations of earlier ones and free us from some earlier limitations, it introduces new one's of its own (Wertsch, del Rio, & Alvarez, 1995). Indeed, these empirical cycles of testing and refinement revealed the need for opportunities in the designed pedagogical model, and consequently, in the related, conceptual object-oriented learning system (figure 1).

In general, the conceptual model of the object-oriented learning system, with its broadened definition of learning objects, seemed to be vital in designing and constructing the virtual environment, as it recognized the significance of different individual perspectives, and this supported the negotiation of meaning when designing the museum visits. The process of designing the museum visit was anchored to the learners' own ideas and thoughts, and when given free choice, it seemed that the nature of the objects that the students set themselves determined the basic features of the emerging process (Hakkarainen et al., 2013). The primary school students' design process emphasized descriptive knowledge, and was significantly mediated by the tools, which became the premise for the choice of the research perspective, and the research object. The technical college students' questions were mostly procedural and adaptive in nature, and the process of design was more object-oriented. The teacher-education students approached the design environment from the point of view of their own research interests, representing mainly strategic and conditional knowledge. Consequently, a tool-driven system typically seemed to represent the approach of primary school students, with an object-driven system for technical college students, and a strategic, research-question-driven system for teacher-education students. The empirical studies also revealed the need for the shared object for learning to connect the students' inquiries together, to mediate the types of social processes that characterize collaborative-knowledge work better (Bereiter & Scardamalia, 2003).

The first conceptual model of the object-oriented learning system considered the subject of the system to be an individual and/or a group of learners. The analysis of the social settings of the subjects in different phases of the learning process revealed that in all groups, the designing of the museum visit emphasized collaborative activities. Although we were able to promote students' collaborative designing when planning the museum visit, the model did not sufficiently articulate the role of museum experts in the learning system. Although LCD deliberately breaks the boundaries of traditional schoolwork by involving experts, such as museum staff, with students' collaborative inquiry (Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010), this empirical study revealed that the actualization of the designed activities in the museum posed a clear need to consider the interaction between the students and the experts deeply. The balance in the learning system was enhanced by modifying the social settings from guide-centered lecturing about the student-selected inquiry topic toward supporting active discussions and collaboration between student groups and museum experts.

In designing the prototype of the virtual environment, the role of tools was based on representing diverse physical and cognitive tools that could enhance the students' abilities to integrate them into their own inquiries. Although the results of the study indicated the importance of providing tools that (forestry) expertise rests on, at the same time, we came to recognize the need for tools to externalize and record the activities around artifacts inside of the museums, and to organize and share the collected data from the museum. Thus, the students' own technologies (digital cameras) and wiki environment were added to the design with the case of pre-service teachers. Consequently, these needed changes in the tool environment challenged the theory-driven division of physical and cognitive tools in the conceptual model, as we came

to ponder if these students' hybrid technologies (e.g., smart phones) and social tools such as wiki augmented their physical and/or cognitive activity. When considering the desired effects of technology and open environments on emerging learning systems and processes, we concluded that there was a need to take into account the variation in student approaches, the design-process scaffolding, and paying attention to the social arrangements, and to the use of tools during the implementation of the inquiry activities.

5.2 DEVELOPMENT OF THE DESIGN IN EXPERIMENT 2

Vartiainen, H. & Enkenberg, J. (2014). Participant-led photography as a mediating tool in object-oriented learning in museum. *Visitor Studies, 17*(1), 66–88.

5.2.1 Aims and refinement of the design

In terms of the lessons learned for the next iteration, we developed both the conceptual model and the related instructional model toward more participatory modes of learning. The goal of the second design experiment (study II) was to further develop and explore the conceptual framework and instructional model for learning in museums. In the refinement of the design, the learning task was added as an element to the system. It aimed to emphasize the role of the shared object in orienting the interactions of the subjects, tools, and artifacts. Although this was based on the same principles of engaging students in open-ended and multifaceted design tasks, the emphasis was changed from designing the museum visit to the construction of learning objects from physical museum artifacts. Consequently, the learning object was reconsidered to be an outcome of interactions within the learning system, which may be meaningful not only to the constructing subjects themselves (e.g., the small student group), but also potentially to the other participants of the learning system (e.g., the student community, museum professionals), and to future museum visitors. For such a process, the role of mediating artifacts was considered to be multidimensional - both conceptual (students questions, theories, ideas) and material (creation of digitally embodied artifacts) (Seitamaa-Hakkarainen, Viilo, & Hakkarainen, 2010).

The previous experiment revealed the need to pay attention to the interaction between the students and the experts. Thus, instead of just focusing on collaboration between the student and their peers (cf. figure 3) in the learning system, the second conceptual framework (figure 8) aimed to emphasize the participation perspective. This was actualized by inviting the students to participate in the activities of the expert organization by producing design resources for different study groups arriving at the museum (cf. experiment 1), and modeling the role of museum experts to support this process by participating in the negotiation of meaning with the students, offering suggestions, and providing feedback, and by guiding them to appropriate knowledge resources.

As in the previous study, the deliberate efforts at encouraging students to use their own personal tools seemed to offer new possibilities for learning in museums,

where the digital cameras served as the main tool in making visible, reflecting on, and transforming the design-oriented practices. In addition, the wiki environment as a social tool served as a platform for collaboration and the construction of the learning objects. Figure 8 presents the second conceptualization of the design-oriented learning system in the museum, in which people, artifacts, and tools constitute an interacting system in the co-development process of learning objects.

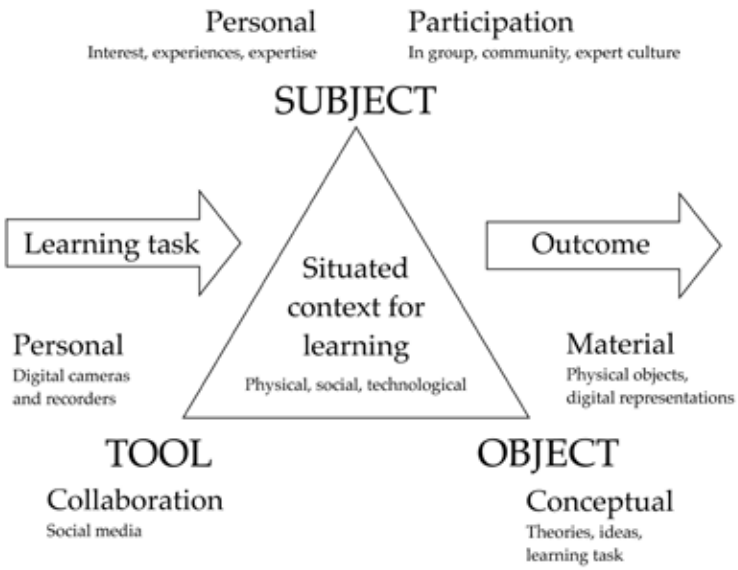

Figure 8. The second conceptual framework of design-oriented pedagogy in museums.

Such changes in the learning system also required developments in the instructional model. The project activity was divided into four main phases, which took place partly at the school, partly in the museum, and partly in the technological environment. Instead of using digital representations of museum artifacts, in the second model, the negotiation of the students' own research questions was carried out through interaction with the physical museum environment. After the first museum visit, the designing of the learning objects was expected to continue at the school, followed by the documentation of the learning objects during the second museum visit. The final phase was to process the collected materials as learning objects to be shared with a wider audience in the wiki environment. Figure 9 describes the redeveloped instructional model.

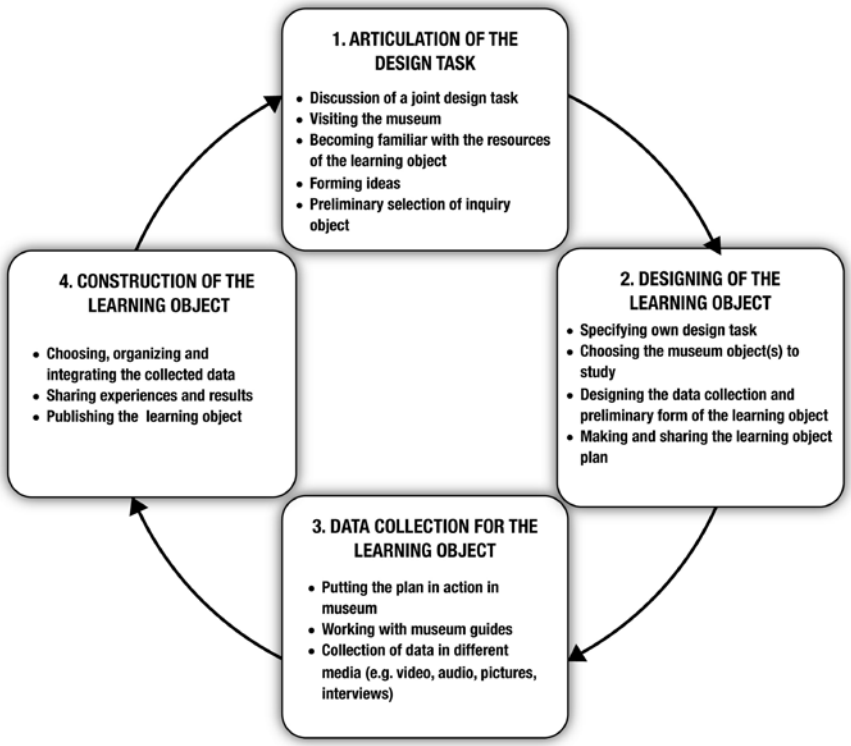

Figure 9. The applied instructional model of study II.

5.2.2 Cycle of testing the design

The second iteration took place in the spring of 2008, when the teacher-education students in the second-year class (N = 20) implemented a learning project for a Finnish Forest Museum at Lusto. When reflecting on the changes in the learning system, we first investigated how the students experience and engage themselves in this kind of activity by comparing the two teacher-education groups involved (case 3 in experiment 1 implementing the first instructional model and the case in experiment 2 implementing the second instructional model). To measure the students' engagement and experiences in relation to the instructional model, the students were asked to participate in a questionnaire based on the dimensions of Fredricks, Blumenfeld, and Paris's (2004) construct, designed on a five-point Likert scale, and implemented after the learning process (see article IV).

In comparison to the other studies, study II was particularly focused on the investigation of how participant-led photography could facilitate the learning process in museum settings, and provide a methodological tool for analyzing the nature of tool-enhanced and object-oriented collaborative design activities. The specific research interest in the second experiment was on 1) how the learning system is represented in the students' photographs, and 2) what kind of activities are mediated in the tool-enhanced and design-oriented learning in a museum.

5.2.3 Reflections on the design

The second conceptual model of the learning system recognized the role of the design task in orienting the interactions between subjects, artifacts, and tools. The empirical study indicated that the design task allowed the students to self-define and negotiate their areas and objects of interest, supported and extended by museum experts. The content analysis of the students' photographs and the videotapes from the selected, small-group students' photographic episodes indicated that when the design process advanced, the activities in the museum transformed from artifact-related observations to involve knowledge-seeking explanations of their own inquiry questions.

Another difference in this second model was that the learning object was represented as an outcome of the design process to be shared beyond the student community for the use of other museum visitors. When comparing the design task of the first and the second instructional model, in both, the learners are working in teams with museum artifacts as they address their own research questions. However, the practices that the learner is a part of in the first model did not include the possibility for the students to contribute to the museum community. This might have important implications for the meaning and type of practices being learned, as well as for the students' relations to those meanings and practices (Barab & Duffy, 2000). When considering the effects of extending the nature of the shared learning task, the results of the second experiment suggest that the students valued the opportunity to contribute their own ideas and insights to the institution, and they used significant efforts to create outcomes that were meaningful not only to the students themselves, but also potentially to the other participants of the learning system, and to future museum visitors. On the other hand, the results of the questionnaire that was set to measure the students' engagement indicated that the deep cognitive processing that was achieved was done partly at the cost of emotions (see article IV). It seems that for some students, there was not a robust enough scaffolding to support the challenging situations and confusion that the students experienced when facing and creating solutions to the task.

The analysis of tool-mediated activities indicated that use of participant-led photography strengthened and expanded the mediational potential of an artifact, and provided students the ability to reshape, represent, and embed the physical objects in relation to their own interest. The use of the tool seemed to be influenced by the context of the museum visit (e.g., articulation of the design task, construction of learning objects) and by the forms of the activity (e.g., making, thinking, sharing). When comparing the content of the teacher-education students' photos in the design experiments 1 (study I) and 2 (study II), it also seems that the instructional model influenced how the students chose to construct the photographic data for themselves during their museum visits.

5.3 ENLARGEMENT OF THE DESIGN IN EXPERIMENT 3

Vartiainen, H., & Enkenberg, J. (2013). Reflections of design-oriented pedagogy for sustainable learning: An international perspective. *Journal of Teacher Education for Sustainability, 15*(1), 43–53.

5.3.1 Aims

According to Bielaczyc (2013), over time and across the stages of development, the DBR may result in the design of an intervention that has reached a point of stability, has a recognizable identity, and has been shown to lead to desired learning processes and outcomes. The model is specified in enough detail to be adopted by others outside of the development efforts, and the next step involves a push to scale up these innovations in order to bring innovative reforms to life in schools (Bielaczyc, 2013). After several stages of development and prototyping the research of the DOP model (cf. article IV; Liljeström, Enkenberg & Pöllänen, 2013b; Liljeström, Vartiainen & Enkenberg, 2009; see Appendix 1), our next step was to achieve a fuller implementation of the pedagogical model (figure 10).

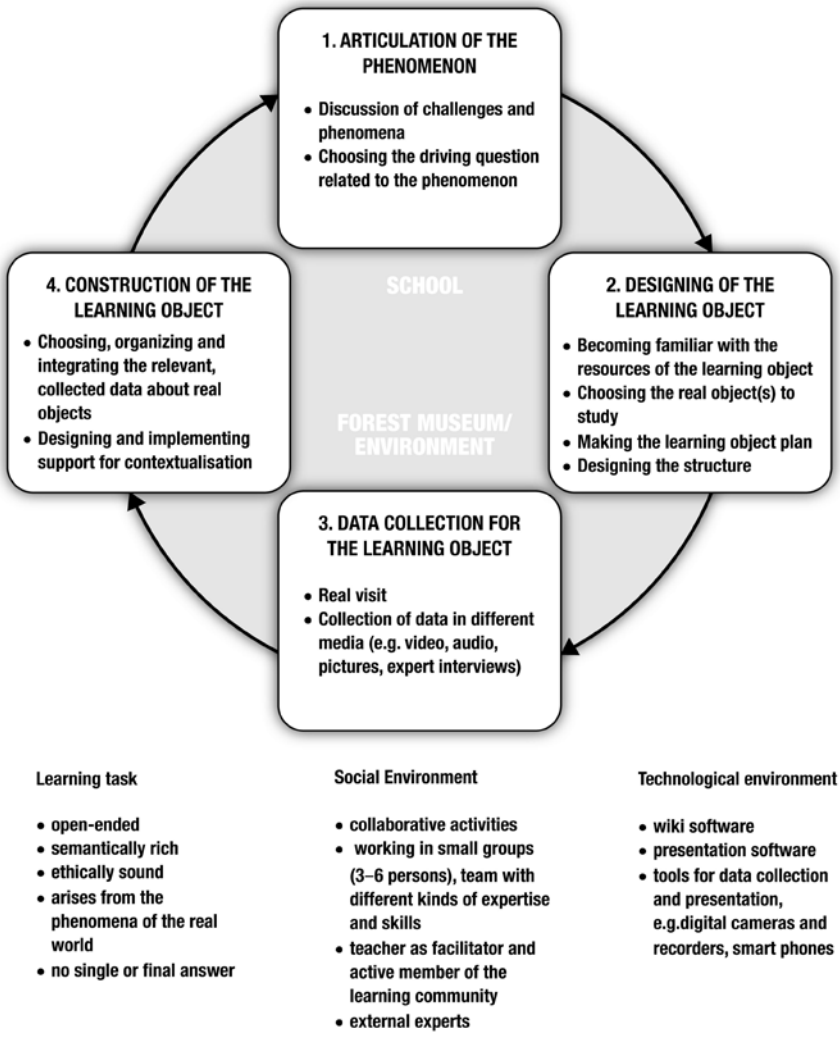

Figure 10. The applied instructional model of study III.

At this point, the structure of the design-oriented learning environment was described as a dynamic activity system, where a community of learners negotiates common goals, divides their duties, and focuses their object-oriented and tool-mediated activities to accomplish the multifaceted learning task (Engeström, 1987). The learning community consisted of a student, fellow students, and teachers, working with domain experts and other adults. New technology, especially social media and mobile technologies, provided tools for collaboration, and data collection, and helped to transform ideas into digital representations that could be jointly negotiated, developed, and shared with a wider community.

5.3.2 Cycle of testing of the design

The third design experiment presented in this thesis was carried out in the 'Case Forest–Pedagogic towards Sustainable Development' (Comenius) Project with project members and teachers ($N = 221$) from eight different European countries. The project aimed to increase knowledge about forests by facilitating teaching and improving learning in schools, and the instructional approach in implementing that was based on DOP. In the spring of 2009, the project participants and two teachers from each country attended a workshop in Finland. In this model course, the participants implemented their own learning projects related to the common theme of sustainable development by designing learning objects from the collections of the Finnish Forest Museum Lusto. Then, a similar course was arranged in every country. The project members and teachers attending the model course were responsible for implementing this teacher course in each country, with ten teachers per course. The final meeting was held in Bulgaria in the summer of 2010, in which the project members shared their experiences about the model. The main sources of data were the reports obtained from each country, and transcripts of the oral presentations and collaborative discussions from the final seminar.

In light of the entirety of the thesis work, the project opened up the possibility of being able to explore both teachers' perspectives on a variety of elements underlying the learning system, and particular contextual issues that may affect implementation (cf. Bielaczyc, 2013). The particular research interest was to find out what the problems could be, alongside the possibilities and possible users of the DOP according to the participating teachers, and how the teachers of the project envisioned the possibilities of the DOP.

5.3.3 Reflections on the design

The DOP is based on a co-developmental process that emphasizes students' active agency in articulating the learning task, and in selecting the artifacts and tools for inquiry. While the teachers perceived the pedagogy as an effective approach to facilitating a sustainable future and recognized the need of research-based instructional models, they also reflected strongly on the existing practices in which the teachers are used to organizing the components of the learning system. Apparently, the dominant structures were also reflected in the negative attitudes on the use of technologies and new pedagogical approaches, and the challenges of co-operation between the teachers. The findings of the study support Zhang's (2010) argument that successful

innovation requires teachers to commit to and maintain sustained effort to break away from their existing practices in reconstructing new agency for themselves. However, it can be argued that the networks of teachers, researchers, and domain experts should work together to accomplish such a challenging task.

Teachers also reflected on the influence of the contextual factors that are shaping the system. One particular and pervasive challenge experienced by the teachers was how to bring such a new model into existence within their own schools, especially when the current classroom context is often very different from the educational framework conceptualized by the developed model (Bielaczyc, 2013). For example, the teachers reported a tension between creating new practices and in the obligation (to varying degrees) to follow the curriculum. The teachers interested in developing their practices are required to work in an school system that may have a very different motive, one which is often focused on shaping students to fit a predetermined model by means of the delivery of a curriculum, and to assess that they do so (Wells, 2011). The teachers also need to adjust in the external construct of the school, such as in the strict division between school subjects and lessons. Some of the Eastern European countries also experienced problems related to the political regulations around education and the financial constraints of learning institutes. These findings suggest that when bringing a new educational model to life, a variety of contextual challenges shaped by social and cultural practices in the educational context must be considered. Consequently, the implementation of an educational innovation depends not only on the success of the design, but critically, both also on teachers as well as institutional and larger socio-economic forces that shape their activities.

6 Perspectives on Design-Oriented Pedagogy

The typical characterization of DBR settings as complex and messy emphasizes further the significance of articulating and refining interpretative frameworks (Cobb & Gravemeijer, 2008). In the present study, the perspectives derived from the sociocultural theory of learning and learning by designing served as guidelines to design a draft model that learning theory suggests as productive, and to pursue empirical research to develop such a model. Recognizing the complexity of real-world environments and the contextual limitations, the initial hypotheses and principles needed refining, adding to, and discarding - gradually knitting together previously disparate pieces to create a coherent perspective that reflected our understanding of the design (Amiel & Reeves, 2008; Edelson, 2002).

So far, the summary has provided a description of the development work of the model in museum settings and has articulated some success factors from these experiments. The aim of this chapter is to connect and discuss how the theoretical insights about learning have been transformed, together with the empirical research to enhance design-oriented learning in museums. Finally, the challenges and limitations of the present study will be discussed and elaborated on with new perspectives with potential that should be pursued.

6.1 DESIGN PRINCIPLES

As Amiel and Reeves (2008) point out, while the ultimate objective in DBR is the development of a theory with the outcome of a set of design principles that can be implemented by others interested in creating and studying similar settings and concerns, this might only occur after long-term engagement in iterative cycles of research. Based on perspectives derived from theoretical and empirical investigations, the following elements are articulated and proposed to be part of the design-oriented learning system for learning from and with museum objects.

6.1.1 Artifacts

The reason for entering any museum is typically to view and experience the collection of physical and conceptual objects and artifacts with high cultural value (see Paris et al., 2002). As institutions for the general public, museums are where society collects, preserves, and displays the visible records of its social, scientific, and artistic accomplishments (Leinhardt, Crowley, & Knutson, 2002). We strive to understand the past

and to capture our own lived experiences to leave a legacy for the future through the preservation of historical and cultural artifacts and sites (Giaccardi & Palen, 2008). While the museum-education research and literature emphasizes that learning in museums is based on museum artifacts, it seems to use the concepts of *object* and *artifact* as synonyms, and rather loosely to refer to these material, digital, and conceptual representations of social, scientific, and artistic accomplishments.

Yet, the different meanings for museum objects or artifacts, tools, learning communities, learning objects, etc. caused much thinking during the theory-driven research process in this study. Especially when the notion of the artifact and object seems to be under deep discussion, problematization, and debate under the wide umbrella of sociocultural theory. For example, the "object" has been referred to as individual goals (Barab & Roth, 2006), social or organizational motives (Kaptelinin & Miettinen, 2005), something people act toward and with (Nicolini, Mengis, & Swan, 2012), concrete objects under development (Paavola, Engeström, & Hakkarainen, 2012), or as symbolic-material artifacts (Hakkarainen et al., 2013). Then again, the concept of artifact has been broadly referred to as any instrument or tool that mediates between subjects in interaction and the object of their activity (Leander, 2002), as subsuming that of a psychological tool (Daniels, 2008), and as an overarching concept that includes the subcategory of tools (Cole, 1996). Although these approaches have their own distinctive followers, debates, and studies, they also share a common, basic assumption that human action is mediated by material and symbolic artifacts (Nicolini, Mengis, & Swan, 2012).

According to Wells (2007), the distinction between a tool and artifact is dependent on the context and form of the activity that is mediated. He points out that it is a more general problem with making a sharp distinction between a tool and an artifact or a sign by giving an example:

> When I am digging my vegetable garden, the spade mediates my material activity as I turn over the soil; in this context it is clearly a tool. But if I am interrupted, I may leave the spade at the point I have reached as a sign to "tell" me where I should continue when I return to the task. (p. 245)

Elaborating on his example, when this spade is being preserved as a historical artifact behind the glass window of a museum, it still has a material embodiment that may mediate the human activities associated with the spade differently in different fields and in different genres. Yet, the context and possibilities of being able to use the spade are clearly very different. It may not be used as a tool to realize similar physical activities that are inherent in its origin, but it has a potential to mediate communication, collaboration, and joint problem solving. However, to prevent confusion in, and to connect these theoretical concepts to the practical situations for learning in museums, these definitions have been contextualized in this discussion. By artifact, we refer to the material or conceptual piece in the collections of a museum, which, typically, is manufactured, modified, or used by human beings, or at least is selected for the collections by and for human beings. As argued by Cole (1996), the artifacts have a dual material–conceptual nature, and the mediation through artifacts is related to

the subject and their objects. In this study, however, we contextualized the tools as a means with which to explore the museum artifacts. In addition, the conceptualization of the object is connected to the learning task, and thus, is separated from the first definition provided in the sub-studies in which the object refers to mediating artifacts.

As with the theoretical perspectives above, we aim not to consider the museum artifacts in isolation or as having a meaning without a human subject. Yet, the mediational function of artifacts embedded in human activity brings with it the important question about the situation in which the activities take place and the organization of the activity itself (Daniels, 2008). The meaning and functional role of museum artifacts does not depend solely on the affordances of the museum or the properties of the artifacts, but is mediated by context-bound interactions of the subjects, their intentions, and tools. On the other hand, the critics of the previous research of school fieldtrips to museums indicate that many of the pedagogical practices in museums ignore such a systemic perspective on learning from and with museum artifacts. The guide or the teacher decides what, how, and by which tools one has to learn about the artifacts, and the focus is on the transmission of artifact-related knowledge rather than on object-oriented actions. Although these tours may provide useful insights on some core perspectives and the practices in which the artifacts have their origin, they provide very little guidance on how one could translate them as sources for one's own actions.

Instead of predetermined guided tours in museums, design-oriented learning aims to enhance activities in which students connect with the world around them through the objects and artifacts they self-organize for their own action and thinking. At the beginning of the design process, the physical artifacts or digital representations of them are first encountered without their subjects' clear understanding of their meaning or functional role (Wertsch, 2007). The articulation of the design task and related research questions can be understood from one point of view as identifying, negotiating, and selecting the artifacts that become part of the students' own learning resources, in relation to their own interests, past experiences, and future intentions. In other words, the subjects narrow down potentially successful alternatives as they begin to design their potential artifacts providing access to their intentions (Barab et al., 1999). As noted by Kangas et al. (2011), these intentions guide the design process, but may transform when the process advances. Thus, it is not simply subject(s)–artifact(s) interaction, but includes the process of perceiving the function and meaning of the selected museum artifact in terms of achieving a particular goal. Vygotsky's line of reasoning, the human relationship with the museum artifacts is not considered as constant, but it may develop as they are encountered differently in evolving design processes in which connections are established with other artifacts, tools, and subjects. Furthermore, the museum artifacts can be approached from different perspectives with various questions in mind, and can take on different functions when the students select, and embed them in their own activities. A particular artifact can assume a different meaning for the different students, with the artifact being a focus of inquiry for some, while, at the same time, being a background for others, for example (cf. Nicolini, Mengis, & Swan, 2012). Consequently, an artifact behind the glass window of the museum is rather firm and constant in terms of its physical form, but the meaning that is associated with it may change.

6.1.2 Tools

While the use of tools and technologies seems to be ignored in contemporary museum education (Liljeström et al., 2013c; Vartiainen et al., 2013), the present study emphasizes the relevance of having diverse personal, social, and professional tools that can be intellectual, physical, or mixed. The first model was based on the idea of enhancing the learning process by providing different physical (e.g., measurement tools) and cognitive (e.g., a tree-model) for mediating the knowledge-creating practices of the expert communities. Yet, the empirical study indicated the need for social tools (e.g., wiki) to share the evolving process and expertise, as well as tools to facilitate the examination of the artifacts. Thus, in the subsequent study, the students possessed tools and technologies that were adopted into the design. This clearly supported the inquiry activities and allowed the students to take advantage of those knowledge-creating practices that they use outside of formal educational settings.

When reflecting on the development of the tool perspective, we came to realize that the tools derive their full meaning and functional role in relation to the other components of the learning system in situated social practice; the subject(s) using the tools (e.g., students, experts, and teachers' agency), the object (e.g., shared tasks, students' own research questions), and artifacts of their actions (e.g., material and conceptual), and the context of using the tools (e.g., designing, making inquiries, sharing). Thus, the subject and artifacts are not connected by the tool in a mechanical manner, but are dynamic interactions, and are grounded in particular activities. Different tools are needed during the process of designing and implementing the inquiry activities in museums, and during this evolving process, the same tool may be used in different ways, and may serve different purposes.

According to Wertsch, del Rio, and Alvarez (1995), tools usually emerge for reasons other than to facilitate many kinds of actions that they end up shaping. This notion is particularly topical in the twenty-first century, as new tools and technologies are invented constantly, typically outside of the educational institutions. Since progress in the past has always been made by seeing new uses for existing ideas and technologies, and by discovering novel applications and inventions, it is important to create flexible tool environments for the design process that encourage the students to adopt an innovative and creative stance (Wells, 2008). As Claxton (2002) argues, if the main thing we know about the future is that we do not know much about it, then the educators should not only provide young people with the tools of today, but should help them to become confident and competent designers and makers of their own tools and tool environments when solving emergent problems.

6.1.3 Subjects

Drawing on sociocultural perspectives, one important dimension by which learning from and with museum artifacts may be facilitated on school trips would be students' interactions with others - with their peers, with museum staff, and with teachers (DeWitt & Hohenstein, 2010). As argued by Vygotsky, learning is best enhanced when the learners receive support in their ZPD while engaged in a shared activity with an adult or more capable peer. In DOP, this is supported by promoting the possibility of being able to use the students' own interests as a basis for the process of using

the artifacts as resources for collaborative activities undertaken with more mature members of the culture, such as the museum professionals. Nevertheless, with this clearer understanding of the overall dynamics of the learning system, we came to see that there were tensions in the ways in which the experts and students positioned themselves in relation to each other and the museum artifact.

As argued by Wells (2007), the meaning potential depends on the particular social groups to which the students belong, as well as on the characteristic ways in which meaning is jointly constructed in the groups concerned, and the cultural resources to which they have access. The empirical studies indicated that self-organization and free choice are indeed driven by the social groups to which the students belong (e.g., primary school class, technical college, teacher students) and may not, without the support of the teachers and experts, necessarily lead to research-question-driven learning processes for museum artifacts. Moreover, we came to realize that it was not only the connecting students' interests that supported building the relationship with the artifacts, but that this required a change in the interactions between the students and experts during the museum visits. In other words, it required a change of orientation from just providing artifact-related knowledge from museum expert to novice, toward regarding the artifacts as resources, and as a medium for communication and thinking with others in the pursuit of a shared object. In so doing, the museum professionals as well as the teachers may come to understand the needs of their particular students and how to meet those needs better (Wells, 2008), and may, at the same time, support the students to use, connect, and organize the museum artifacts and other resources (e.g., print and digital information resources) with increasing levels of expertise (Wertsch, 2007).

From a participatory perspective of learning, the extended community is a temporary one and it offers limited opportunities for moving from the periphery to becoming a fully recognized practitioner in the expert community (cf. Barab & Duffy, 2000). With deep connections to theories representing the participation metaphor of learning, the emphasis on DOP diverges from them in respect of being more focused on connected learning as an essential aspect of collaborative work. It aims to break the traditional, isolated school practices by linking the learning process with expert communities and learning resources that can support students' as well as teachers' learning on demand (NETP, 2010). Akkerman and Bakker (2011) have argued that in current society learning is not only about becoming an expert in a particular bounded domain, but also about crossing boundaries. As noted by Kumpulainen and Lipponen (2012), this also calls for supporting the students' possibilities for boundary crossing, and for enhancing their active role in organizing their own learning during these transitions.

6.1.4 Design task

The important instructional feature of the learning system is the design task, which orients and structures the activities emerging in the network of the subject, tools, and museum artifacts. This view overlaps with Hakkarainen et al.'s (2013) notion of trialogical inquiry that requires the participants to go beyond mere dialogues (e.g., around museum artifacts in this case) to develop shared objects. Emphasizing the

developmental relationship with the museum artifacts, the shared object is negotiated and developed in the DOP system through an open-ended design task. The design task aims to connect the heterogeneous interests, desires, and experiences that learners bring to the museum from other contexts with the affordances of the learning environment and for the use of the learning community. Thus, the activities in the museum are driven by the students' own research questions, in which they attempt to produce answers that will advance their own and others' understanding (Wells, 2008).

While there might be a rather established social environment (e.g., students, teachers, museum experts) and specified affordances (e.g., museum, collection of tools, artifacts, and other resources) in certain learning projects, what further distinguishes this approach from traditional museum visits is that the learners themselves define the specific network of artifacts, tools, and other resources in terms of their own research questions and intentions. At best, inside a particular learning community, the learners work with the same multifaceted phenomena, but from different perspectives mediated by diverse artifacts, tools, and other resources. It includes the intention of creating small-group activities that mediate that of domain experts (e.g., biologists, anthropologists, engineers, economists), and through collaboration among interdependent, small groups of "disciplinary specialists," the practices of the knowledge-crating pursuits of the group, companies, and organizations, as a whole.

In the first phase of the research, we sought to broaden what it means to "participate" by building a virtual design-environment application that would enhance students' agency in designing their own museum visit beforehand. Based on the findings, it was concluded that a participatory perspective during the design process of the museum visit could have an effect on the process, but only to a limited extent, if the implementation of the students' inquiry activity in the museum did not adequately support participatory forms of learning. Therefore, in the subsequent study, the aim was not only to modify the museum experts' interaction and contribution to the students' inquiry, but to enhance the students' possibilities of becoming involved in culturally and personally relevant activities in which they appropriated the cultural resources to participate in, and contribute to the larger community (cf. Wells, 2010). This was actualized by providing the students with the opportunity to be part of the activities taking place in the surrounding society and making their contributions for it through the co-development of learning objects.

6.1.5 Learning objects

The notion of the learning object in design-oriented learning was defined as "designed digital representations from real objects in context that are related to the phenomenon in question and to tools that mediate the process of the negotiation of meaning" (article IV). In the first phase of the research, the instructional model was anchored on using existing learning objects in which the students designed their inquiries and related research questions with the support of the digital learning objects before the interaction with the actual physical object in the museum. In the second phase, the learning object became the design task as the model emphasized learning by designing learning objects. Thus, the learning objects may serve as design resources for the museum visit (cf. study I) or as an outcome of it (study II). The construction of learning

objects shares the idea of trialogical inquiry by engaging students' learning in creative working with externalized ideas, and the objectification and materialization of thoughts in respect of creating their own (digital) artifacts in interaction with which the subsequent inquiry takes place (Hakkarainen et al., 2013). During the empirical studies, this perspective was extended by participating the students in the creation of outcomes that also build our collective memory. Mediated by the museum expert, artifacts, and tools, the students create newly made interpretations and combinations of museum artifacts and other resources with outcomes that are both personal and collective. The social production of meaning is more than individual interpretation multiplied; it represents a profound change in the ways we make sense of cultural experience (Jenkins et al., 2008) and in how we understand the role of museums in mediating that.

6.1.6 Situated context

Like activity systems (Engeström, 1987), the elements of the DOP system are not static but are continuously interacting with each other, through which they define the learning system as a whole. This emergent form of the system ultimately shifts our focus from the elements to the situated context that they form, and promoting the students' possibilities of shaping it. It proposes a clear transformation from a predetermined learning environment toward the creation of dynamic learning networks. As argued by Liljeström, Enkenberg, and Pöllänen (2013b), the focus is transformed in emerging learning ecosystems that offer the students the opportunity to self-organize and utilize the afforded community, technology, and information resources to construct their own interpretations of their chosen research tasks and related inquiries.

This view overlaps with Barab and Roth's (2006) notion of affordance networks. They define it as the collection of facts, concepts, tools, methods, practices, agendas, commitments, and even people, taken with respect to an individual, that are distributed across time and space, and are viewed as necessary for the satisfaction of particular goal sets. According to Barab and Roth (2006), education should connect learners to an ecological system that stimulates an appreciation for, and a desire to be a part of contexts through which these networks take on meaning, as well as equipping students so that they can create new and useful affordance networks. From this perspective, learning and participation is about successfully participating as part of an ecosystem, which involves increasing the possibilities for action in the world (Barab & Roth, 2006). Similarly, Greeno (1997) argues that learning can be understood as improved participation in interactive systems, in which the participation of each subject is considered in relation to the other subjects and the material and representational systems that contribute to the activity.

As argued by Jenkins et al. (2008), schools, museums, and other public institutions have an essential role to play in creating more equitable opportunities for participating and contributing one's own expertise to a process that involves many intelligences and communities outside of the school. When the students participate in practices to address shared intentions beyond the school, such as with the creation of learning objects for the use of a museum community in this case, the students become, at that moment, an enculturated, participatory, contributing community member, and the

students and the experts community's ecosystems overlap (Barab et al., 1999). At the heart of the idea is to allow students to participate in knowledge creating activities and to share their efforts with their community for further knowledge building that is a legitimate part of civilization (Scardamalia & Bereiter, 2006). To conclude, figure 11 presents a developed learning system of interconnected elements that derive their full meaning in relation to each other.

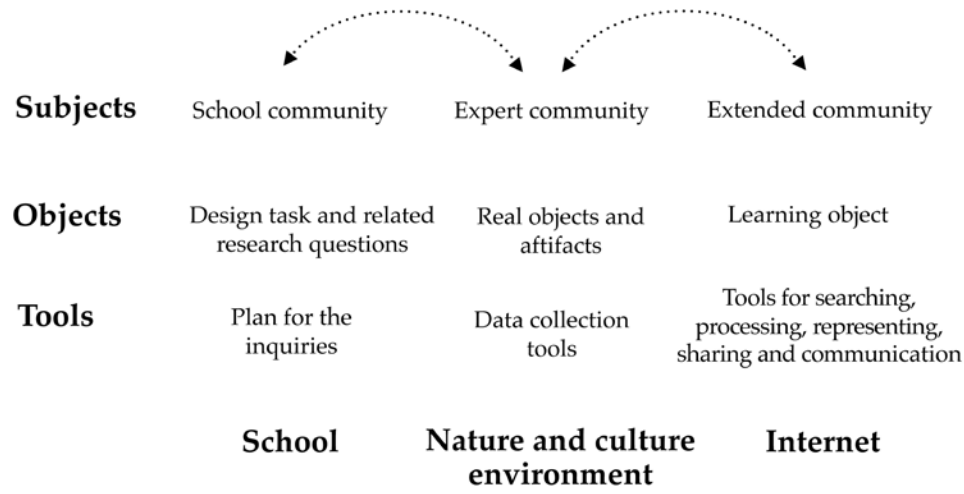

Figure 11. Design-oriented learning process, described as system.

To sum up, the DOP framework offers a pedagogical model and process, together with the underlying conceptual system embodied in the design. The DOP aims to transform learning by paying attention to the ways that diverse people, objects, artifacts, and tools interact with each other, and developing out of the system the best opportunities for learning. The DOP shares several similarities with inquiry-based pedagogies, and particularly, it grounds and contains elements relating to learning by collaborative designing. However, instead of construing artifacts, in this study, the emphasis was more on working with knowledge that is embedded in or bound to physical museum artifacts, and on building interpretations and combinations of the cultural resources with outcomes that contribute to the larger community (article IV).

Participatory perspectives on learning are emphasized in situating the learning in extended environments and generative communities. The learning process is anchored on learners' ideas, thoughts, conceptions, and interpretations about the shared design task, and offers the students opportunities to participate in the co-development process in an evolving way. This participation in an expert community is driven by the students' own interests and research questions, where they work together in teams in pursuit of advancing their own understanding to be shared with the extended community. Furthermore, the DOP utilizes the notion of self-organizing systems of participatory cultures by emphasizing that the process is not scripted in detail in advance, but has to be negotiated and actively designed by the leaners them-

selves. It matters that various resources are available for the use of the learners, but it is essential that the learners should be positioned in a key role when defining the specific network of artifacts, tools, and other resources in terms of their own research questions and intentions. However, the leaners are supported by the instructional model and by joint activities with mature members of the community to build learning paths that mediate the practices of professional or scientific communities (article IV).

In contrast to traditional 'chalk and talk' classrooms in which knowledge is abstracted from real-life situations, the DOP involves collaborative working with conceptual and material artifacts that represent the phenomenon in question. It also aims to enhance the opportunity to apply diverse physical, cognitive, and social tools and technologies in collecting, developing, and sharing information. The technologies that the students own provide tools to enhance learning across different contexts, and to collect various empirical data when implementing inquiries. The learners are also provided with the possibility of being able to use domain-specific tools that characterize such expertise. Additionally, social media provides tools for learners to organize, develop, and share knowledge, and to collaborate within and outside the school community (article IV). However, rather than dealing with technology in isolation, the DOP takes a more systemic approach, by considering the interrelationship among tools, artifacts, and the communities, and the activities in which they are embedded.

Furthermore, the learners are deliberatively provided with the possibility and means through which to share their ideas, thoughts, and their own designs with the extended community in the form of a learning object. A single learning object is not designed to provide a comprehensive description of a particular phenomenon, but several learning objects together may offer different kinds of perspectives and interpretations about it (article IV). As pointed out by Thomas and Brown (2011), promoting the opportunity for the students to share the outcomes of their inquiry activities with an extended collective structured around participation is very different to putting the outcome onto the school wall or into the public domain. By offering the students the chance to collaborate with their peers, to take part in face-to-face interactions with expert communities, and to be involved in mediated contact online with a more dispersed population, the students are offered different forms of participation (Jenkins et al., 2008). Viewed through the lens of participatory culture, this takes us back to the emergence of collective intelligence (Lévy, 2013), and promoting the opportunities for and the means of participating in the practices of the social production of knowledge (Jenkins et al., 2008) in distributed networks of communities, resources, and tools.

Moreover, the DOP encourages working with domain experts. It aims to construct this interaction by using the students' own interests as a basis for collaborative activities undertaken with more mature members of the culture, such as the museum professionals. Yet, this focus on the value of inquiry activities that enables students to participate in the co-development process with (museum) professionals and an extended community stands in striking contrast to the current practices, and we must push further and deeper in this pursuit of collaboration across different learning communities and knowledge networks. One open question concerns how we can deepen the learners' interaction with the external experts, and, on the other hand, better enhance connected learning that supports students to participate in networks that in-

clude experts from various domains (c.f. Mizuko et al., 2013; NETP, 2010, the proposed connected learning model). In a sense, if the process is only anchored in schools, museums, and in technological environments, such as in this study, it also constrains the students' chances of self-regulating their learning processes, and of using various resources, expertise, and networks in a self-organizing manner (c.f. Liljeström, Pöllänen & Enkenberg, 2013a; 2013b). This might be particularly important for learning in a world of constant change in which the use of diverse knowledge resources, tools, and network connections are essential aspects when solving emergent problems and creating situation-based solutions. It also highlights the importance of *design* in 21st-century learning.

6.2 METHODOLOGICAL PERSPECTIVES

According to Lesh, Kelly, and Yoon (2008), the nature of design-based research is rooted in the fact that many of the phenomena that we seek to understand involve systems that are complex, dynamic, interacting, and continually adapting. Soini, Pietarinen, and Pyhältö (2013) argue that if educational phenomena are approached as situated composites rather than isolated ingredients, it means that implementation of new educational ideas requires a systemic approach to research as well. Such a systemic perspective does not mean that the basic ingredient studies, for example, sub-studies focusing on a certain aspect or element of the system, should be replaced by composite studies, but rather that the latter should complement the former. The power of the DBR emerges in its potential to design and study different aspects within the system and how they interact with each other, which may give a greater understanding of the learning ecology.

From the perspective of development work related to the present study, the shared interests that schools, museums, and educational research have on education was indeed the driving force for the collaboration of many actors with different viewpoints and roles (e.g., museum professionals, forest scientists, technological designers, educational researchers, teachers), and still is. In a sense, it could be seen as a shared problem space or as a *boundary object;* a motive for the activity of boundary crossing and of shared activity between diverse stakeholders (Akkerman & Bakker, 2011). According to Akkerman and Bakker (2011), the boundary in the middle of two activity systems represents the sociocultural difference and the possible difficulty in action and interaction between these systems, but it also represents the potential foundation for communication, collaboration, and for a process of transformation.

However, the notion of boundaries is often associated with the so-called third generation of sociocultural theory that extends beyond the scope of the preset study. Engeström (2001, 2011) describes the three generations in the evolution of sociocultural theory from the perspective of activity theory as follows. He refers to Vygotsky's identification of the systemic interactions of subject, object, and mediational means as the first generation of the activity theory. In the first generation, the prime unit of analysis is centered on mediated action. The second generation broadened the scope of Vygotsky's mediated action by turning the focus toward interrelations between the

individual subject and community, and it took the collective activity system as its unit of analysis. Such an activity system is also mediated by the rules that constrain or liberate the activity and provide guidance, as well as by the division of labor negotiated among the community. The third generation of activity theory expanded toward the networks of interacting activity systems, in which a collective, artifact-mediated, and object-oriented activity system is represented in relation to other activity systems. The units of analysis are at least two activity systems, which have a partially shared object.

Engeström (2011) criticizes how design-based researchers typically use the notion of systems, components, and dynamical learning environments on a very general level, and how the unit of analysis is vague. In this study, the starting point was in problems related to school fieldtrips, as expressed by the museum professionals as well as in the educational literature and research. From the point of view of this research, the challenge is that real-life problems needing a solution did, and do not exist solely in schools nor in museums, and, on the other hand, learning and context are considered as inseparable. One of features of the problem was also that the school groups visiting museums came from various backgrounds and from different school levels, which challenged us to pursue a more general pedagogical contribution. To meet these challenges, Vygotsky's basic triangle together with instructional perspectives derived from later interpretations, represented as a theoretical construct at a rather conceptual level, and provided the means for designing the draft model through which the pragmatic design experiments were formed. However, when we connected the subject, object, and mediational means together with the instructional perspectives derived from learning by designing, the implementation of the actual pedagogical design also challenged us to reconceptualize the learning system itself. Thus, both the pedagogical model and system representing it were modified, and different elements were elaborated on and studied in the design experiments. Consequently, the unit of analysis did not remain the same across the iterative experiments in which the aim was to develop both the pedagogical model and the conceptual model representing the anatomy of the design-oriented learning system. In a sense, the interaction between the theory and practice that is highlighted in design-based research was actualized in this study through the development of the learning system together with the pedagogical model that aims to produce the realization of that system in practice.

Engeström (2011) also criticizes how the process of design research is depicted in a linear fashion, associated with notions of perfection, completeness, and finality. Typically, the researchers produce the design, the teachers implement it (and may contribute to its modification), and the students will potentially learn better as a result (but the students do not participate in the actual design process). Accordingly, such a view ignores the agency of both practitioners and students. As Bielaczyc (2012) points out, design-based research involves two layers of design: the design as conceived by the developers of the model and the designs as constructed by teachers and learners when adapting the model to the local context of use, in which the participants make several design decisions regarding how to organize their activities (Bielaczyc, 2012). In this study, in addition to the collaboration between researchers and practitioners when developing the model, the active role of the participants was emphasized

by building the design based on previously discussed theoretical and instructional perspectives of learning that emphasize participation, learning by designing, and self-organization of the emerging learning system. The investigation of the participants' own designs also opened up opportunities to explore their perspectives on the elements involved in the educational model (Bielaczyc, 2012).

From the subject perspective, the study exhibits a deliberate effort to include a wide range of participants from specific groups of people who are relevant to the phenomenon, and thus would enable exploration of particular aspects of it (Mays & Pope, 1995). When we began the research work (study 1), the students were rather passive objects of study, and the researchers brought knowledge from the theories and developed the model through observations, video recordings, and interviews (Sanders & Stappers, 2008). As the design process progressed, the students in the second study played a larger role in data generation, which can be seen as a shift toward participative modes of research in which those who have agreed to become involved in a study have produced some or even all of the data (Prosser & Loxley, 2008) as a part of their own leaning projects. In the third phase, the teachers from diverse backgrounds merged their efforts to share their thoughts, ideas, and visions about the model with other teachers and researchers. Such a process could be characterized more as co-development, as the teachers were participating in evaluation, further development, and the adjustment of the model. Thus, as the design process evolved, the relationship with the participant was also transformed. As noted by Lesh, Kelly, and Yoon (2008), DBR typically requires reconsideration of many traditional roles of researchers and participants. On the other hand, Barab and Squire (2004) note that it is also the responsibility of the design-based researcher to keep in mind that claims are based on researcher-influenced contexts, and, as such, may not be generalizable to other contexts of implementation where the researcher does not so directly influence the context. Design-based researchers are not simply observing interactions, but are actually influencing the same interactions that they are making claims about (Barab & Squire, 2004).

Futrhermore, the empirical research was situated in complex, dynamic learning contexts, where numerous contextual factors, variables, and processes were present and in interaction, and some emerged during the study (Design-Based Research Collective, 2003; Barab, 2006). The causality is difficult to decipher as all of the possible factors cannot logistically be equally pursued and a precise replication of an intervention is largely impossible (Design-Based Research Collective, 2003). To address these concerns, a deliberate effort was made to document the processes by using various data-collection procedures and providing rich descriptions of context, the guiding and emerging theory, the design features of the intervention, and the impact that these features seemed to have for participation and learning (Barab & Squire, 2004).

Also the evolving nature of the design under study posed clear research challenges. It is an unpredictable design-process in which questions and procedures are emergent. Roth (2005) points out that the fundamental aspect in design-based research is its evolving character, in that an intervention is changed when something is not working, which also entails changes in the work of the researcher. During the process of research, we needed to search for methods that were sensitive enough to

guide an empirical exploration in each stage of the design process. The role of data collection was also to foster the re-definition of the design, and the formulation of new research problems and procedures that might best address the current state of the design. As pointed out by Cobb and Gravemeijer (2008), the decisions about the types of data that need to be generated in the experiments also depend on the theoretical intention of the study because the data have to make it possible to address broader theoretical issues of which the learning intervention under investigation is a pragmatic case. Although DBR research procedures are flexible and may evolve during the study (Barab, 2006), there were sometimes difficulties in balancing the relationship between the design and the empirical research of the design. For example, in relation to the rapid advancements of the technology, new tools were rather easy to add to be part of the pedagogical design, but the analysis of their impact, and their relationship to the other components of the learning system was much more difficult and slower. On the other hand, the systemic perspective requires that the evaluation function and meaning of tools and technologies set to enhance learning in museums cannot be divorced from the instructional practices that organize the activities. Another problem associated with the strategy of design research concerns the threat of data overload, and this was apparent in the present study. The large amount of data collected from each experiment led us to difficult choices regarding what data should be analyzed and which data should be left alone. In turn, it also offered the possibility to triangulate from multiple sources to evaluate the intended and unintended outcomes from the processes of enactment (Design-Based Research Collective, 2003).

As argued Soini et al., (2013), the richness of the DBR poses many challenges to the study and to researchers, because it requires theoretical, developmental, and methodological designing in each phase of the complex process. Creating the linkages between theory and design, and between several iterations of the design, requires rigorous methods, but never totally ruling out alternative explanations (Barab, 2006). Edelson (2002) argues that the objective of design research is different from traditional empirical research, and it should not be judged by the same standards. The two important evaluation metrics for design research are novelty and usefulness (Edelson, 2002). Plomp (2009) argues that in the case of design research, the researcher should strive to generalize "design principles," which should be tested through several iterations in various contexts with the purpose that the same results should occur. However, the aim of the present study was not to optimize a pre-designed pedagogical model with a series of sub-studies with one school level of learners or teachers, nor to understand, for example, how different types of learners use the same tools in the different sub-studies. Although it is not possible to make any definitive conclusions about the pedagogical design and its relationship with learning, each sub-study revealed some advancements, and contradictions that were not observed previously. As pointed by Roth (2007), instead of discussing generalizability, one might focus more on transferability; that is, about the extent to which the developed model and theoretical insights are applicable and useful in another contexts. The present study is based on sub-studies that build on one another. Moreover, several experiments not reported in this thesis have also validated the instructional model and related pedagogical principles (Liljeström, Enkenberg, & Pöllänen, 2013a, 2013b, Liljeström, Vartiainen,

& Enkenberg, 2009). It is also important to recognize that while the designed pedagogical model may have been supported by a number of iterations, each context has unique characteristics that highlights that it should be used as a "heuristic" tool providing guidance and direction (Plomp, 2009).

Although the study adheres to the notion of close relationships to the participants, the researcher did the data analysis. To improve the analysis procedures and results, they were shared and discussed in the research group involving experienced researchers. The support of the research group was a clear asset during the other phases of the study as well, as it offered the possibilities to negotiate, develop, share, and reflect together in various situations of the complex design-based research. Consequently, this thesis is a part of co-development work enabling multiple researchers and practitioners representing different practical and/or theoretical perspectives to work together at multiple sites over several years (Lesh, Kelly & Yoon, 2008).

When conducting DBR in an educational setting, we also needed to ponder the ethics behind research activity. The empirical studies were conducted according to the ethical guidelines of the National Advisory Board on Research Ethics (2009). Although experiments were carried out as part of the Comenius Project (study III) and of the studies in schools and at a university (studies I & II), the participation in the research was voluntary. At the beginning of each experiment, we described the objective of the research, the data-collection procedures, and emphasized the fact that the study did not evaluate the performance of the individual learner, and that the individual subjects' identities would not appear in the research reports. Although each participant could refuse to take part in the research or deny the use of data concerning him or her personally, no one did so. Permission to collect and use the data for research purposes was obtained from all participants, including guardian permission for subjects under the age of 15. The ethical concerns of publishing photographs including students (study II) were kept in mind by providing the pre-service teachers with the autonomy to produce the data. To conclude, the selection and justification of DBR as a research method was considered to be an ethical commitment to the promotion of improvements in educational practice.

6.3 FUTURE DIRECTIONS

Summing up these experiments and development work, there is evidence that the DOP model can fruitfully be applied in diverse contexts for enhancing participatory learning situated across spaces (see also Liljeström, Enkenberg, & Pöllänen, 2013a, 2013b). Yet, the pedagogical design is not considered to be at a point of finality and perfection, but still continues to be refined as part of an evolving design research process (Bielaczyc, 2013). After these rather small-scale design experiments, the next step in this longitudinal DBR is the enlargement of these innovations.

While the DOP has been studied over eight years in several case studies, there are many open questions requiring more widespread and extensive studies with diverse target groups. For example, it is not clear to what extent DOP combined with learning-system thinking may enhance a deeper understanding of domain knowledge and

of learning twenty-first-century skills. These investigations are needed to generate more specific scientific knowledge and understanding concerning the possibilities and constraints of the pedagogy. Furthermore, the existence of problems associated with assessing such learning projects and processes calls for further research. An interesting future step might be to develop technologies to dynamically track, visualize, and share the progress of learning, and the growing system during the course of action. At the same time, it would provide researchers with interesting opportunities to examine how and in what ways the students of different educational backgrounds use their own interests, their own and afforded technologies, and extended physical and social environments as resources for learning.

Furthermore, when moving beyond the traditional model of educators and students in classrooms to a learning model that brings together students, museums, and expert communities, the new forms of collaboration and practices for sharing expertise present a very complex challenge. One can argue that most of the experts in different organizations have no experience of this kind of pedagogical approach that lie outside of their area of expertise. Thus, it requires extensive investigations of how diverse experts become part of the learning system, and how a reciprocal relationship for learning may be facilitated. The DOP also requires technologies and tools that enhance such cultures of participation. Therefore, the research team of the larger DBR, representing multidisciplinary expertise concerning educational and forest sciences and museum experts, has constructed the OpenForest portal (www.openmetsa.fi/) for researchers, experts, teachers, students, and others interested in sharing, developing, and organizing knowledge, and collaborating within, and outside the community of education and institutions. This portal offers interesting possibilities for future research concerning knowledge creation in networked communities.

As pointed by Bielaczyc (2013), one particular future challenge concerns how to support teachers in bringing new pedagogical models into existence within schools. The third study showed that the learning system does not exist in isolation, but is affected and constrained by the institutional and larger socio-economic, even political, forces that shape its emergence. Consequently, it indicates the need for a better understanding and for supporting learning within and between different levels of educational system (e.g., teachers, school leaders, administration) (Soini, Pietarinen, & Pyhältö, 2013). While the implementation of new innovations provided by researchers is difficult, after the third study we have had the opportunity to observe the work of some Finnish project members and teachers, who have organized several workshops for other teachers and several learning projects with their students since their introduction to the model four years ago. These cases provide valuable avenues for future research for sustained innovation and understanding of the new ideas, designs, and practices derived from the DOP.

References

Akkerman, S., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research , 81*(2), 132-169.

Amiel, T., & Reeves, T. C. (2008). Design-based research and educational technology: Rethinking technology and the research agenda. *Educational Technology & Society, 11*(4), 29–40.

Anderson, T., & Shattuck, J. (2012). Design-based research: A Decade of progress in education research? *Educational Researcher, 41* (Jan/Feb), 16-25.

Balsamo, A. (2010). Design. International Journal of Learning and Media, 1(4), 1–10.

Bamberger, Y., & Tal, T. (2009). The learning environment of natural history museums: Multiple ways to capture students' views. *Learning Environments Research, 12*(2), 115-129.

Barab, S. (2006). Design-Based Research: A methodological toolkit for the learning sciences. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 153-169). Cambridge: Cambridge University Press.

Barab, S., Chekes-Julkowski, M., Swenson, R., Garrett, S., Shaw, R., & Young, M. (1999). Principles of self-organization: Learning as participation in autocatakinetic systems. *The Journal of the Learning Sciences, 8*(3&4), pp. 349-390.

Barab, S., & Duffy, T. (2000). From practice fields to communities of practice. In D. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (pp. 26-56). Mahwah: Lawrence Erlbaum Associates.

Barab, S., & Kirshner, D. (2001). Methodologies for capturing learner practices occurring as part of dynamic learning environments. *The Journal of The Learning Sciences, 10* (1&2), 5–15.

Barab, S., & Roth, W-M. (2006). Curriculum-Based Ecosystems: Supporting knowing from an ecological perspective. *Educational Researcher, 35*(5), 3-13.

Barab, S., & Squire, K. (2004). Design-Based Research: Putting a stake in the ground. *The Journal of the Learning Sciences, 13*(1), 1-14.

Bell, P., Lewenstein, B., Shouse, A., & Feder, M. (2009). *Learning science in informal environments. People, Places, and Pursuits.* Washington, D.C: National Academies Press.

Bereiter, C., & Scardamalia, M. (2003). Learning to work creatively with knowledge. In E. De Corte, L. Verschaffel, N. Entwistle, & J. van Merriënboer (Eds.), *Powerful learning environments. Unraveling basic components and dimensions* (pp. 55-68). Oxford, UK: Elsevier Science.

Bielaczyc, K. (2013). Informing design research: Learning from teachers' designs of social infrastructure. *The Journal of the Learning Sciences , 22*(2), 258-311.

Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., & Rumble, M. (2011). Defining 21st century skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 17–66). New York: Springer.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences , 2*(2), 141-178.

Brown, J.S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher, 18*(1), 32-42.

Bryman, A. (2012). *Social Research Methods 4th edition*. Oxford, UK: Oxford University Press.

Bucciarelli, L. L. (2001). Design knowing & learning: A socially mediated activity. In C. Eastman, M. McCracken & W. Newstetter (Eds.), *Design Knowing and Learning: Cognition in design education* (pp. 297-314). Oxford, UK: Elsevier Science.

Chi, M. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences, 6*(3), 271–315.

Churchill, D. (2005). Learning object: An interactive representation and a mediating tool in a learning activity. *Educational Media International, 42*(4), 333–349.

Claxton, G. (2002). Education for the learning age: A sociocultural approach to learning to learn. In G. Wells & G. Claxton (Eds.), *Learning for Life in the 21st Century* (pp. 21-34). Oxford: Blackwell.

Clinton, K., Jenkins, H., & McWilliams, J. (2013). New literacies in an age of participatory culture. In H. Jenkins & W. Kelley (Eds.), *Reading in a participatory culture: Remixing Moby-Dick in the English classroom* (pp. 3-23). New York: Teachers College Press.

Cobb, P., Confrey, J., diSessa, A., Lehrer, R., & Schauble, L. (2003). Design experiments in educational research. *Educational Researcher, 32*(1), 9-13.

Cobb, P., & Gravemeijer, K. (2008). Experimenting to support and understand learning processes. In A. E. Kelly, R. A. Lesh, & J. Y. Baek (Eds.), *Handbook of design research methods in education. Innovations in science, technology, engineering and mathematics learning and teaching* (pp. 68-95). Mahwah, NJ: Lawrence Erlbaum Associates.

Cole, M. (1995). Socio-cultural-historical psychology: Some general remarks and a proposal for a new kind of cultural-genetic methodology. In J. Wertsch, P. del Rio, & A. Alvarez (Eds.), *Sociocultural studies of mind* (pp. 187-214). New York: Cambridge University Press.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Cole, M., & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.) *Distributed cognitions: Psychological and educational considerations* (pp. 1-46). Cambridge: Cambridge University Press.

Cole, M., & Engeström, Y. (2007). Cultural-historical approaches to designing for development. In J. Valsiner & A. Rosa (Eds.), *The Cambridge handbook of sociocultural psychology* (pp. 484-507). Cambridge: Cambridge University press.

Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New Directions in Educational Technology* (pp. 15-22). New York: Springer Verlag.

Confrey, J. (2006). The evolution of design studies as methodology. In K. Sawyer (Ed.), *The Cambridge Handbook of the Learning Sciences* (pp. 135-152). Cambridge: Cambridge University Press.

Cox-Petersen, A., Marsh, D., Kisiel, J., & Melber, L. (2003). Investigation of guided school tours, student learning, and science reform: recommendations at a museum of natural history. *Journal of Research in Science Teaching, 40*(2), 200-218.

Daniels, H. (2008). *Vygotsky and Research*. London: Routledge.

Daniels, H., Cole, M., & Wertsch. J. V. (2007). Editor´s Introduction. In H. Daniels, M. Cole, & Wertsch. J. V. (Eds.) *The Cambridge Companion to Vygotsky* (pp. 1-20). Cambridge : Cambridge University Press.

Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher, 32*(1), 5–8.

DeWitt, J., & Hohenstein, J. (2010). School Trips and Classroom Lessons: An Investigation into Teacher-Student Talk in Two Settings. *Journal of Research in Science Teaching, 47*(4), 454-473.

DeWitt, J., & Storksdieck, M. (2008). A short review of school field trips: Key findings from the past and implications for the future. *Visitor Studies, 11*(2), 181-197.

Dillon, P., & Howe, T. (2003). Design as narrative: objects, stories and negotiated meaning. *International Journal of Art and Design Education, 22*(3), 291-298.

Eckert, P., Goldman, S. & Wenger, E. (1997) The School as a Community of Engaged Learners. *Institute for Research on Learning, Stanford*. Retrieved Jan 28, 2014, from http://www.stanford.edu/~eckert/PDF/SasCEL.pdf.

Edelson, D. C. (2002). Design research: What we learn when we engage in design. *Journal of the Learning Sciences, 11*(1), 105–121.

Edwards, A. (2007). An Interesting Resemblance: Vygotsky, Mead and American Pragmatism. In H. Daniels, M. Cole, & Wertsch. J. V. (Eds.) *The Cambridge Companion to Vygotsky* (pp. 77-100). Cambridge : Cambridge University Press.

Engeström, Y. (1987). *Learning by expanding: an activity-theoretical approach to developmental research*. Helsinki: Orienta-Konsultit.

Engeström, Y. (2001). Expansive learning at work: toward an activity theoretical reconseptualization. *Journal of Education and Work, 14*(1), 133-156.

Engeström, Y. (2011). From design experiments to formative interventions. *Theory & Psychology, 21*(5), 598–628.

Engeström, Y., & Blackler, F. (2005). On the life of the object. *Organization, 12*(3), 307-330.

Enkenberg, J. (1993). Situation graphs as tools for ordering of students thinking and understanding of actual existing servo mechanisms. In: B. Dennis (Ed.), *Control technology in elementary education* (pp. 133–150). NATO ASI Series, Springer-Verlag, Berlin Heidelberg.

Enkenberg, J. (2001). Instructional design and emerging teaching models in higher education. *Computers in Human Behavior, 17*(5–6), 495–506.

Eshach, H. (2007). Bridging in-school and out-of-school learning: formal, non-formal and informal education. *Journal of science education and technology, 16*(2), 171-190.

Fischer, G. (2013). Learning, social creativity, and cultures of participation. In A. Sannino, & V. Ellis (Eds.), *Learning and collective creativity: Activity-theoretical and sociocultural studies* (pp. in press). New York: Taylor & Francis/Routledge.

Francis, R. (2007). *The Predicament of the Learner in the New Media Age*. D. Phil. Oxford University.

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59 – 109.

Frost, C. (2002). When the object is digital: Properties of digital surrogate objects and implications for learning. In S. Paris (Ed.), *Perspectives on object-centred learning in museums* (pp. 37–54). Mahwah NJ: Lawrence Erlbaum Associates.

Gerber, B., Marek, E., & Cavallo, A. (2001). Development of an informal learning opportunities assay. *International Journal of Science Education, 23*(6), 569 - 583.

Giaccardi, E., & Fitzcarrald, F. (2004). Memory and territory: New forms of virtuality for the museum. Museums and the web 2004. Retrieved Jan 28, 2014 from http://www.archimuse.com/mw2004/papers/giaccardi/giaccardi.html

Giaccardi, E., & Palen, L. (2008). The social production of heritage through cross-media interaction: making place for place-making. International Journal of Heritage Studies, 14 (3), 282-298.

Greeno, J. G. (1997). On claims that answer the wrong questions. *Educational Researcher, 26*(1), 5-17.

Griffin, J. (1998). Learning science through practical experiences in museums. *International Journal of Science Education, 20*(6), 655-663.

Griffin, J. (2004). Research on students and museums: Looking more closely at the students in school groups. *Science Education, 88*(11), 59–70.

Griffin, J., & Symington, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education, 81*(6), 763–779.

Gutwill, J., & Allen, S. (2012). Deepening students' scientific inquiry skills during a science museum field trip. *Journal of the Learning Sciences, 21*(1), 130–181.

Hakkarainen, K. (1998). *Epistemology of inquiry and computer-supported collaborative Learning*. Unpublished Ph.D. thesis. University of Toronto.

Hakkarainen, K. (2010). Communities of learning in the classroom. In K. Littleton, C. Wood, & J. Kleine Staarman (Eds.), *International handbook of psychology in education* (pp. 177–225). Bingley, UK: Emerald. Retrieved Jan 28, 2014, from https://www.academia.edu/350358/Draft_of_Hakkarainen_K_2010_Communities_of_learning_in_the_classroom

Hakkarainen, K., Paavola, S., Kangas, K., & Seitamaa-Hakkarainen, P. (2013). Socio-cultural perspectives on collaborative learning: Towards collaborative knowledge creation. In C. Hmelo-Silver, C. Chinn, C. Chan & A. O'Donnell (Eds.), *International handbook of collaborative learning* (pp. 57-73). New York: Routledge.

Harden, R., Gessner, I., Gunni, M., Issenberg, S., Pringle, S. & Steward, A. (2011). Creating an e- learning module from learning objects using a commentary or 'personal learning assistant'. *Medical Teacher, 33*, 286–290.

Harel, I. (1991). *Children designers*. Norwood, NJ: Ablex.

Hauser, W., Noschka-Roos, A., Reussner, E. & Zahn, C. (2009). Design-based research on digital media in a museum environment. *Visitor Studies, 12*(2), 182-198.

Hawkey, R. (2004). Learning with digital technologies in museums, science centres and galleries. *Futurelab SERIES*. Future Lab. Retrieved Aug 05, 2013, from http://archive.futurelab.org.uk/resources/documents/lit_reviews/Museums_Galleries_Review.pdf.

Hennessy, S. (2011). The role of digital artefacts on the interactive whiteboard in mediating dialogic teaching and learning. *Journal of Computer-Assisted Learning, 27*(6), 463-586.

Hennessy, S., & Murphy, P. (1999). The potential for collaborative problem solving in design and technology. *International Journal of Technology and Design Education, 9*(1), 1–36.

Herrington, J., & Reeves, T. (2011). Using design principles to improve pedagogical practice and promote student engagement. In *Proceedings of ASCILITE - Australian Society for Computers in Learning in Tertiary Education Annual Conference 2011*, (pp. 594-601).

Hmelo, C., Holton, D.L., & Kolodner, J. (2000). Designing to learn about complex systems. *Journal of the Learning Sciences, 9*(3), 247-298

Hoadley, C. (2004). Methodological Alignment in Design-Based Research. *Educational Psychologist, 39*(4), 203-212.

Hodgins, H. (2002). The future of learning objects. In D. A. Wiley (Ed.), *The Instructional Use of Learning Objects* (pp. 281-298). Bloomington, Indiana: AIT/AECT. [Online]. Retrieved Jan 05, 2013, from http://reusability.org/read/

Hyysalo, S. (2005). Objects and motives in a product design process. *Mind, Culture, and Activity, 12*(1), 19-36.

Illich, I. (1972). *Kouluttomaan yhteiskuntaan. (Deschooling society, 1971.)* Suomentanut Aarne Valpola. Delfiinikirjat. Helsinki: Otava

Institute of Electrical and Electronics Engineers' Learning Technology Standards Committee IEEE. (2005). *The Learning Object Metadata Standard*. Retrieved Jan 28, 2014, from http://ltsc.ieee.org/wg12/

Jarvis, T., & Pell, A. (2005). Factors influencing elementary school children's attitudes toward science before, during, and after a visit to the UK National Space Centre. *Journal of Research in Science Teaching, 42*(1), 53–83.

Jenkins, H., Clinton, C., Purushotma, R., Robison, A. J., & Weigel, M. (2008). *Confronting the challenges of participatory culture: Media education for the 21st century.* Chicago, IL: John D. and Catherine T. MacArthur Foundation. Retrieved Jan 28, 2014, from http://www.nwp.org/cs/public/print/resource/2713

Johnson, B., & Onwuegbuzie, A. (2004). Mixed Methods Research: A Research Paradigm Whose Time Has Come. *Educational Researcher, 33*(7), 14-26.

John-Steiner, V. & Mahn, H. (1996). Sociocultural approaches to learning and development: A Vygotskian framework. *Educational Psychologist, 31*(3/4), 191-206.

Jonassen, D., & Churchill, D. (2004). Is there learning orientation in learning objects. *International journal of E-Learning* , April-May, 32-42.

Joseph, B., & Charnecki, K. (2013). Leveraging digital media to create a participatory learning culture among incarted youth. In A. Delwiche & D. Henderson, The *Participatory cultures handbook* (pp. 220-231). New York: Routledge.

Juuti, K., & Lavonen, J. (2006). Design-based research in science education: One step towards methodology. *NorDiNa: Nordic Studies in Science Education, 4*, 54–68.

Kangas, K., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2011). Design expert's participation in elementary students' collaborative design process. *International Journal of Technology and Design Education, 2*3(2),161-178.

Kaptelinin, V. & Miettinen, R. (2005). Perspectives on the Object of Activity. *Mind, Culture, and Activity, 12*(1), 1-3.

Kisiel, J. (2005a). An examination of fieldtrip strategies and their implementation within a natural history museum. *Science Education, 90*(3), 434–452.

Kisiel, J. (2005b). Understanding elementary teacher motivations for science fieldtrips. *Science Education, 89*(6), 936–955.

Kodoner, J. (2002). Facilitating the learning of design practices.: Lesson learned from an inquiry in science education. *Journal of industrial teacher education*, *39*(3), 1-31.

Kozma, R. (2011). A framework for ICT policies to transform education. In R. Kozma (Ed.) *Transforming education: The power of ICT policies* (pp. 19–36). Paris, France: UNESCO.

Kozulin, A., Gindis, B., Ageyev, V. S. and Miller, S. M. (2003) Introduction: Sociocultural Theory and Education: Students, Teachers, and Knowledge. In A. Kozulin, B. Gindis, V. S Ageyev, & S. M. Miller, (Eds.) *Vygotsky's Educational Theory in Cultural Context* (pp. 1-14). Cambridge: Cambridge University Press.

Krajcik, J., & Blumenfeld, P. (2006). Project-based learning. In K. Sawyer (Ed.), *The Cambridge handbook of the learning sciences* (pp. 317–333). Cambridge: Cambridge University Press.

Kress, G. (2003). *Literacy in the New Media Age*. New York: Routledge.

Kumpulainen, K., & Lipponen, L. (2012). Crossing boundaries: Harnessing funds of knowledge in dialogic inquiry across formal and informal learning environments. In P. Jarvis, & M. Watts (Eds.), *The Routledge International Handbook of Learning* (pp. 112-125). London : Routledge.

Lahti, H. (2008). *Collaborative design in a virtual learning environment: three design experiments in textile teacher educ*ation. Helsinki: Helsingin Yliopisto. (Kotitalous- ja käsityötieteiden laitoksen julkaisuja; 17).

Lahti, H., Seitamaa-Hakkarainen, P., & Hakkarainen, K. (2004). Collaboration patterns in computer supported collaborative designing. *Design Studies, 25*(4), 351-371.

Laru, J. (2012). *Scaffolding learning activities with collaborative scripts and mobile devices*. Acta Universitatis Ouluensis. Series E, Scientiae rerum socialium 125 / University of Oulu 2012.

Law, N., Pelgrum, W., & Plomp, T. (2008). *Pedagogy and ICT use in schools around the world: Findings from the IEA SITES 2006 study.* Hong Kong: Springer.

Leander, K. (2002). Locating Latanya: The situated production of identity artifacts in classroom interaction. *Researh in the Teaching of English, 37*, 198-250.

Leinhardt, K., Crowley, K., & Knutson, K. (Eds.) (2002). Learning conversations in museums. Mahwah, NJ: Erlbaum.

Lemke, J. (2002). Becoming the village: Education across lives. In G. Wells, & G. Claxton (Eds.) *Learning for Life in the 21st Century* (pp 34-45). Oxford: Blackwell Publishers.

Leontiev, A. N. (1978). *Activity, consciousness, and personality.* Englewood Cliffs, NJ: Prentice Hall.

Lesh, R., Kelly, A., & Yoon, C. (2008). Multitiered design experiments in mathematics, science and technology education. In A. Kelly, R. Lesh, & J. Baek (Eds.), *Handbook of design research methods in education: Innovations in science, technology, engineering and mathematics learning and teaching* (pp. 131–148). New York: Routledge.

Lévy, P. (2013). The Creative Conversation of Collective Intelligence. In A. Delwiche & D. Henderson (Eds.), *The Participatory cultures handbook* (pp. 99-108). New York: Routledge.

Liljeström, A., Enkenberg, J., & Pöllänen, S. (2013a). Making learning whole: An instructional approach for mediating the practices of authentic science inquiries. *Cultural Studies of Science Education, 8*(1), 51–86.

Liljeström, A., Enkenberg, J., & Pöllänen, S. (2013b). The case of design-oriented pedagogy: What students' digital video stories say about emerging learning ecosystems. Education and Information Technologies. doi:10.1007/s10639-013 9284-6

Liljeström, A., Vartiainen, H., & Enkenberg, J. (2009). Luonto- ja kulttuuriympäristöön liittyvien oppimisaihioiden suunnittelu ja tuottaminen yhteisöllisenä oppimisprojektina. *Interaktiivinen tekniikka koulutuksessa 2009 -konferenssin tutkijatapaamisen artikkelit.* Tampere University Press, Interaktiivisen median tutkimuksia - Research of Interactive Media 2.

Liljeström, A., Vartiainen, H., Vanninen, P., Enkenberg, J., & Pöllänen, S. (2013c). First-year teacher education students reflections and interpretations about sustainable development and enhancing learning practices. In T. Issa, N. M. Sharef, T. Issa & P. Isaías (Eds.), *Proceedings of the International Conference on Sustainability, Technology and Education* (STE2013) (pp.53-63). IADIS Press.

Lipponen, L., & Kumpulainen, K. (2011). Acting as accountable authors: Creating interactional spaces for agency work in teacher education. *Teaching and Teacher Education 27*(5), 812–819.

Loi, D., & Dillon, P. (2006). Adaptive educational environments as creative spaces. *Cambridge Journal of Education, 36*(3), 363-381.

Lombardi, M. (2007). *Authentic learning for the 21st century: An overview*. Retrieved Nov 15, 2007, from https://net.educause.edu/ir/library/pdf/ELI3009.pdf

Matusov, E., St. Julien, J., Lacasa, P., & Alburquerque Candela, M. (2007). Learning as a communal process and as a byproduct of social activism. *Outlines: Critical Social Studies, 1*(1), 21-37.

Mayring, P. (2000). Qualitative content analysis. *Forum: Qualitative social research, 1*(2), 120-130.

Mays, N., & Pope, C. (1995). Qualitative Research: Rigour and qualitative research. *BMJ* (311),109-112.

McDonald, G., Le, H., Higgins, J., & Podmore, V. (2005). Artifacts, tools, and classrooms. *Mind, Culture, and Activity, 12*(2), 113-127.

Miettinen, R., & Virkkunen, J. (2005). Epistemic Objects, Artefacts and Organizational Change. *Organization, 12* (3), 437-456.

Mizuko, I., Gutiérrez, K., Livingstone, S., Penuel, B., Rhodes, J., Salen, K., Schor, J., Sefton-Green & Watkins; S.C. (2013). *Connected Learning: An Agenda for Research and Design*. Irvine, CA: Digital Media and Learning Research Hub.

Morgan, D. L. (2007). Paradigms lost and pragmatism regained. Methodological implications of combining qualitative and quantitative methods. *Journal of Mixed Methods Research, 1*(1), 48-76.

Murphy, P., & Hennessy, S. (2001). Realising the potential - and lost opportunities - for peer collaboration in a D&T setting. *International Journal of Technology and Design Education, 11*(3), 203-237.

Muukkonen-van der Meer, H. (2011). *Perspectives on knowledge creating inquiry in higher education*. Doctoral dissertation, University of Helsinki, Institute of Behavioural Sciences, Studies in Psychology, 75. Helsinki: Helsinki University Print.

Mäkitalo, Å., Jakobsson, A., & Säljö R. (2009). Learning to reason in the context of socioscientific problems. Exploring the demands on students in 'new' classroom activities. In K. Kumpulainen, C. Hmelo-Silver & M. Cesar (Eds.), *Investigating classroom interaction. Methodologies in Action* (pp. 7–26). Rotterdam: Sense Publishers.

National Education Technology Plan. (2010). *Transforming American education. Learning powered by technology*. Retrieved Aug 05, 2013, from www.ed.cov/technology/netp-2010.

National Advisory Board on Research Ethics. (2009). *Ethical principles of research in the humanities and social and behavioural sciences and proposals for ethical review*. Retrieved Jan 20, 2013 from http://www.tenk.fi/eettinen_ennakkoarviointi/ ethicalprinciples.pdf

Nicolini, D., Mengis, J., & Swan, J. (2012). Understanding the role of objects in cross-disciplinary collaboration. *Organization Science, 23*(3), 612-629.

Nicolopoulou, A., & Cole, M. (2010). Design experimentation as a theoretical and empirical tool for developmental pedagogical research. *Pedagogies: An International Journal, 5*(1), 61-71.

Organisation for Economic Co-operation and Development. (2010). Finland: Slow and steady reform for consistently high results. Retrieved Feb 13, 2014 from http://www.oecd.org/pisa/pisaproducts/46581035.pdf

Paavola S & Hakkarainen K (2008) Pragmatisistinen välittyneisyys uuden luomisen perustana. In E. Kilpinen, O. Kivinen, & S. Pihlström S (Eds.) *Pragmatismi filosofiassa ja yhteiskuntatieteissä* (pp.162–184). Helsinki, Gaudeamus.

Paavola, S., Engeström, R. & Hakkarainen, K. (2012). Trialogical approach as a new form of mediation. In A. Morsh, A. Moen, & S. Paavola (Eds.) *Collaborative knowledge creation: Practices, tools, and concepts* (pp. 1-14).Rotterdam: Sense Publishers.

Paris, S., & Hapgood, S. (2002). Children learning with objects in informal learning environments. In S. Paris (Ed.), *Perspectives on object-centred learning in museums* (pp. 37-54). Mahwah: Lawrence Erlbaum Associates.

Pea, R., & Lindgren, R. (2008). Video collaboratories for research and education: an analysis of collaboration design patterns. *IEEE Transactions on Learning Technologies, 1*(4), 235-247.

Penuel, W. Fishman, B., Cheng, B., & Sabelli, N. (2011). Organizing Research and Development at the Intersection of Learning, Implementation, and Design. *Educational Researcher, 40*(7), 331-337.

Perkins, D. (1986). *Knowledge as design*. Hillsdale NJ: Erlbaum Asssociates.

Plomp, T. (2009). Educational design research: An introduction. In T. Plomp & N. Nieveen (Eds.), *An introduction to educational design research* (pp. 9–36). Enschede: SLO.

Prosser, D., & Eddisford, S. (2004). Virtual museum learning. *Information Technology in Childhood Education Annual*, 1, 281–297.

Prosser, J., & Loxley, A. (2008). Introducing visual methods. *National Centre for Research Methods Review Paper No. 10.* Retrieved Jan 28, 2014, from http://eprints.ncrm.ac.uk/420/

Pöllänen, S., & Vartiainen, L. (2013). Forest-themed learning games as a context for learning via collaborative designing of crafts. *Techne Series: Research in Sloyd Education and Craft Science, 20*(3), 33-49.

Rajala, A., Hilppö, J., Lipponen, L., & Kumpulainen, K. (2013). Expanding the Chronotopes of Schooling for Promotion of Students' Agency. In O. Erstad & J. Sefton-Green (Eds.), *Identity, Community, and Learning Lives in the Digital Age*, (pp. 107-125). Cambridge: Cambridge University Press.

Reeves, T. (2006). Design research from a technology perspective. In J. van den Akker, K. Gravemeijer, S. McKenney, & N. Nieveen (Eds.), *Educational design research* (pp. 52-66). London: Routledge.

Rennie, L., & Johnston, D. (2004). The nature of learning and its implications for research on learning from museums. *Science Education, 88*(1), 4-16.

Resnick, L. (1987). *Education and learning to think*. Washington, DC: National Academy.

Rheingold, H. (2013). Participatory pedagogy for a literacy of literacies. In A. Delwiche, & D. Henderson (Eds.), *The Participatory cultures handbook* (pp. 215-219). New York: Routledge.

Rogoff, B. (1995). Observing sociocultural activity on three planes. J.V. Wertsch, P. del Rio, & A. Alvarez, (Eds.), *Sociocultural studies of mind* (pp.139-163). New York: Cambridge University Press.

Roth, W.-M. (1998). *Designing communities*. Dordrecht: Kluwer Academic.

Roth, W.-M. (2005). *Doing qualitative research: Praxis of methods*. Rotterdam: Sense Publishers.

Roth, W.-M. (2007). *Doing teacher research: A handbook for perplexed practitioners*. Rotterdam: Sense Publishers.

Roth, W.-M. (2001). Modeling design as situated and distributed process. *Learning and Instruction, 11*(3), 211–239.

Roth, W-M., & Lee, Y. J. (2006). Contradictions in theorizing and implementing communities. *Educational Research Review, 1*(1), 27-40.

Rowe, J. (2002). The Role of Objects in Active, Distributed Meaning-Making. In S. Paris (Ed.), *Perspectives on object-centred learning in museums* (pp. 19-35). Mahwah: Lawrence Erlbaum Associates.

Sahlberg, P. (2010). Rethinking accountability for a knowledge society. *Journal of Educational Change, 11*(1), 45-61.

Salen, K., Torres, R., Wolozin, L., Rufo-Tepper, R. & Shapiro, A. (2011). Quest to Learn: Developing the School for Digital Kids. *The John D. and Catherine T. MacArthur Foundation Reports on Digital Media and Learning*. London: The MIT Press.

Sanders, E., & Stappers, P. (2008). Co-creation and the new landscapes of design. *CoDesign, 4*(1), 5-18.

Sawyer, K. (2013). Qualitative Methodologies for Studying Small Groups. In C. Hmelo-Silver, C. Chinn, C. Chan & A. O'Donnell (Eds.), *International handbook of collaborative learning* (pp. 126-148). New York: Routledge.

Sawyer, K. (2002). Unresolved Tensions in Sociocultural Theory: Analogies with Contemporary Sociological Debates. *Culture & Psychology, 8* (3), 283-305.

Scardamalia, M. (2001). Big change questions "Will educational institutions, within their present structures, be able to adapt sufficiently to meet the needs of the information age? *Journal of Educational Change, 2*(2), 171–176.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 97–118). New York, NY: Cambridge University Press.

Scardamalia, M., Bransford, J., Kozma, R., & Quellmalz, E. (2011). New assessments and environments for knowledge building. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and teaching of 21st century skills* (pp. 231–300). New York, NY: Springer.

Schank, R. (2011). *Teaching minds. How cognitive science can save our schools.* New York: Teachers College Press.

Schauble, L., Leinhardt, G., & Martin, L. (1997). A framework for organizing a cumulative research agenda in informal learning contexts. *Journal of Museum Education, 22* (2), 3-8.

Schoultz, J., Säljö, R., & Wyndhamn, J. (2001). Heavenly talk: Discourse, artifacts, and children's understanding of elementary astronomy. *Human Development, 44*(2–3), 103–118.

Seitamaa-Hakkarainen, P., Kangas, K., Raunio, A., & Hakkarainen, K. (2012). Collaborative design practices in technology mediated learning. *Journal of Design and Technology Education, 17*(1), 54–65.

Seitamaa-Hakkarainen, P., Viilo, M., & Hakkarainen, K. (2010). Learning by collaborative design: Technology-enhanced knowledge practices. *International Journal of Technology and Design Education, 20*(2), 109–136.

Sfard, A. (1998). On two metaphors for learning and the danger of choosing just one. *Educational researcher, 27*(2), 4-13.

Soini, T., Pietarinen, J., & Pyhältö, K. (2013). Design research approach in the large scale educational innovations. In I. Haslam, M. Khine & I. Salen (Eds.), *Large scale school reform and social capital building* (pp. 70-92). New York: Routledge.

Stavrova, O., & Urhahne, D. (2010). Modification of a school programme in the Deutsches Museum to enhance students' attitudes and understanding. *International journal of science education, 32*(17), 2291-2310.

Säljö, R. (2010). Digital tools and challenges to institutional traditions of learning: Technologies, social memory and the performative nature of learning. *Journal of Computer Assisted Learning, 26*(1), 53–64.

Säljö, R. (2003). Representational tools and the transformation of learning. In B. Wasson, S. Ludvigsen & U. Hoppe (Eds.), *Designing for Change in Networked Learning Environments* (pp. 1-2). Netherlands: Kluwer Academic Publishers.

Tal, T., & Morag, O. (2007). School visits to natural history museums: Teaching or enriching? *Journal of Research in Science Education, 44*(5), 747–769.

Thomas, D., & Brown, J. (2011). A new culture of learning: Cultivating the imagination for a world of constant change. Lexington, KY: CreateSpace.

Valtonen, T., Hacklin, S., Kontkanen, S., Hartikainen-Ahia, A., Kärkkäinen, S., & Kukkonen, J. (2013). Pre-service teachers' experiences of using social software applications for collaborative inquiry. *Computers & Education, 69, November 2013*, 85–95.

Vartiainen, H., Liljeström, A., Enkenberg, J., Vanninen, P. & Pöllänen, S. (2013). Opintoretket ja -vierailut oppimisessa. Presentation in *Kasvatustieteen Päivät 2013,* Jyväskylä, Finland.

Vuojärvi, H. (2013). *Conceptualising Personal and Mobile Learning Environments in Higher Education—Focus on Students' Perspective*. Acta Universitatis Lapponiensis 266. University of Lapland, Faculty of Education, Centre for Media Pedagogy. Rovaniemi: University of Lapland.

Vygotsky, L. S. (1978). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1981). The instrumental method in psychology. In J. V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp.134-143). Armonk, NY: M. E. Sharpe.

Wang, F., & Hannafin, M. (2005). Design-based research and technology: Enhanced learning environments. *Educational Technology Research and Development, 53*(4), 5–23.

Wells, G. (2007). Semiotic mediation, dialogue and the construction of knowledge. *Human Development, 50*(5), 244–274.

Wells, G. (2008). Dialogue, inquiry and the construction of learning communities. In B. Lingard, J. Nixon and S. Ranson (Eds.), *Transforming Learning in Schools and Communities: The Remaking of Education for a Cosmopolitan Society* (pp. 236-256). London: Continuum.

Wells, G. (2010). Schooling: the contested bridge between individual and society. *Pedagogies: An International Journal, 5*(1), 37-48.

Wells, G. (2011). Motive and motivation in learning to teach. In D. M. McInerney, R. A. Walker, & G. A. DLiem (Eds.), *Sociocultural theories of learning and motivation: Looking back, looking forward: Vol. 10. Research on sociocultural influences on motivation and learning*, (pp. 87-107). Charlotte, NC: Information Age Publishing Inc.

Wells, G., & Claxton, G. (2002). Introduction: Sociocultural perspectives on the future of education. In G. Wells & G. Claxton (Eds.), *Learning for Life in the 21st Century* (pp. 1-17). Oxford: Blackwell Publishing.

Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.

Wertsch, J. V. (2007). Mediation. In H. Daniels, M. Cole, & Wertsch. J.V. (Eds.) *The Cambridge Companion to Vygotsky* (pp. 178-192). Cambridge : Cambridge University Press.

Wertsch, J. V., del Rio, P., & Alvarez, A. (1995). Sociocultural studies: History, action, and mediation. In J.V. Wertsch, P. del Rio, & A. Alvarez, (Eds.), *Sociocultural studies of mind* (pp.1-34). New York: Cambridge University Press.

Wertsch, J. V. (1995). The need for action in sociocultural research. In J.V. Wertsch, P. del Rio, & A. Alvarez, (Eds.), *Sociocultural studies of mind* (pp. 56-74). New York: Cambridge University Press.

Wiley, D. (2000). Connecting learning objects to instructional design theory: A definition, a metaphor, and a taxonomy. In D. Wiley (Ed.), *The instructional use of learning objects: Online version*. Retrieved Aug 07, 2013, from http://www.reusability.org/read/.

Wiley, D. (2007). The learning objects literature. In M. Spector, D. Merril, J. van Merriënboer, & M. Driscoll (Eds.), *Handbook of research for educational communications and technology* (pp. 345–354). New York: Lawrence Erlbaum Associates.

Yin, R. (2009). *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage Publications.

Zhang, J., Scardamalia, M., Reeve, R., & Messina, R. (2009). Designs for collective cognitive responsibility in knowledge building communities. *Journal of the Learning Sciences, 18*(1), 7–44.

Zhang, J. (2010). Technology supported learning innovation in cultural contexts. *Educational technology research and development, 58*(2), 229–243.

Appendices

APPENDIX 1.

Development of the design-oriented pedagogy (design experiments from 2005–2011)

Design experiment	Year	Participants	Reported in this thesis. The main context is the museum and the focus is on object-oriented learning and emerging learning systems.	Reported by Liljeström et al. The main context is the nature environment and the focus is on science learning, self-organization, and learning ecosystems.
1	2005	Multi-age students (9–12 years old) (N = 19)		Liljeström, A., Enkenberg, J., & Pöllänen, S. (2013). Making learning whole: An instructional approach for mediating the practices of authentic science inquiries. *Cultural Studies of Science Education, 8*(1), 51–86.
2	2007–2008	Primary school group (N = 17) Technical college students (N = 7) Teacher-education student group (N = 14)	Vartiainen, H & Enkenberg, J. (2013). Learning from and with museum objects: Design perspectives, environment, and emerging learning systems. *Educational Technology Research & Development, 61*(5), 841–862.	
3	2008	Teacher-education student group (N = 20)	Vartiainen, H. & Enkenberg, J. (2014). Participant-led photography as a mediating tool in object-oriented learning in museum. *Visitor Studies, 17*(1), 66–88.	
4	2008	Teacher students (N = 70)		Liljeström, A., Vartiainen, H., & Enkenberg, J. (2009). Luonto- ja kulttuuriympäristöön liittyvien oppimisaihioiden suunnittelu ja tuottaminen yhteisöllisenä oppimisprojektina. *Interaktiivinen tekniikka koulutuksessa 2009 -konferenssin tutkijatapaamisen artikkelit*. Tampere University Press, Interaktiivisen median tutkimuksia - Research of Interactive Media 2.

5	2009	Multi-age students (6–12 years old) (N = 32)		Liljeström, A., Enkenberg, J., & Pöllänen, S. (2013). The case of design-oriented pedagogy: What students' digital video stories say about emerging learning ecosystems. *Education and Information Technologies*. doi: 10.1007/s10639-013 9284-6.
6	2009–2010	International teacher group (N = 221)	Vartiainen, H. & Enkenberg, J. (2013). Reflections of design-oriented pedagogy for sustainable learning: An international perspective. *Journal of Teacher Education for Sustainability, 15*(1), 43–53.	
7	2011	Multi-age students (9–12 years old) (N = 15)		Liljeström, A., Enkenberg, J., & Pöllänen, S. (Submitted). Crowdsourcing to study multidisciplinary and complex phenomenon in a cultural context. *Interactive Learning Environments.*
Summary presenting the Design-oriented pedagogy with four examples of previously presented design experiments.			Vartiainen, H., Liljestrom, A., & Enkenberg, J. (2012). Design-oriented pedagogy for technology-enhanced learning to cross over the borders between formal and informal environments. *Journal of Universal Computer Science, 18*(15), 2097–2119.	

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Principles for Design - Oriented Pedagogy for Learning from and with Museum Objects

To enhance our students' chances of becoming active agents in their own learning, this design-based research aims to synthesize theoretical perspectives and empirical research in order to propose an approach to participatory learning that leverages the opportunities afforded by new technology, cultural environments, and communities, especially museums. The developed research-based pedagogical model with elaborated design principles may help educators in different institutions to facilitate connected learning across spaces and communities.

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