Journal of Universal Computer Science, vol. 18, no. 15 (2012), 2097-2119
submitted: 10/1/12, accepted: 11/6/12, appeared: 1/8/12 © J.UCS

Design-Oriented Pedagogy for Technology-Enhanced Learning to Cross Over the Borders between Formal and Informal Environments

Henriikka Vartiainen
(University of Eastern Finland, Savonlinna Campus, Finland
henriikka.vartiainen@uef.fi)

Anu Liljeström
(University of Eastern Finland, Savonlinna Campus, Finland
anu.liljestrom@uef.fi)

Jorma Enkenberg
(University of Eastern Finland, Savonlinna Campus, Finland
jorma.enkenberg@uef.fi)

Abstract: In this paper, we introduce an instructional model for technology-enhanced learning in the framework of a design-oriented pedagogy. The model is based on the collaborative designing of learning objects representing real objects in nature and culture environments. Project-based learning, whole task approach, object-oriented learning, multiple perspectives and semantically rich objects constitute the framework for a collaborative design process to articulate, build and share knowledge constructed in a community of learners, teacher and experts with the support of social media and mobile technologies. The co-development process supported by socially shared tools will provide possibilities for working with knowledge objects related to the physical, conceptual or cultural artefacts, so that the constructed learning objects can serve as starting points for others to adapt, integrate and develop them further to represent the phenomenon in question. In the paper, the theoretical background of the pedagogy, the instructional model designed and the development of the model will be introduced. Four design experiments demonstrate the applicability of the model in different educational contexts.

Keywords: pedagogical model, learning by collaborative designing, learning object, project-based learning, design-oriented pedagogy
Categories: L.0, L.2

1 Introduction

Many contemporary researchers have emphasised that most of the learning that occurs across a person's life span occurs in various informal and non-formal environments and communities. Learning is a lifelong process (Life-long) that takes place in various situations (Life-wide) and in cultural practices in which we participate (Life-deep). Banks et al. [Banks et al. 2007] proposed that these cultural practices are also the most powerful mediators in learning. However, as illustrated by cognitive scientists, human cognition is not only in the mind of the individual, but also distributed among people, artefacts and applied tools [see Salomon, 1997]. As human beings learn from other people in formal, non-formal and informal settings and from physical and conceptual artefacts and tools with which they interact during daily activities, there is a need to develop new models to enhance learning in natural settings where people interact with environments that lie outside of educational institutes.

The topical challenge in the international educational community is to discover new ways of educating our students to meet the challenges of today's complex world, and for the future. However, the existing situation is a paradox in many ways. The schools seem to behave in a manner that reflects the activities of the past society, where a single educator is transmitting the same information to all learners in the same way. Education systems today support learning, mostly in classrooms and from textbooks [National Education Technology Plan, 2010], and is driven more by content than by linkages to major science concepts, models or practices [Forman and Sink, 2006] or students' experiences in and out of school. The schools and teachers often attempt to cope with the challenges of a heterogeneous student population by designing homogeneous learning paths and by excluding or separating learners with special needs from learning activities [Forman and Sink, 2006]. Not surprisingly, the current school practices fail to engage the hearts and minds of students [National Education Technology Plan, 2010].

To prepare all students to learn throughout their lives and in settings far beyond classrooms, learning environments should be regarded as a kind of extended school environment. In addition to traditional classrooms, they should be built around authentic activities that are situated outside the school as well as around technological tools that can function as bridges between the school and the external environments [Edelson and Reiser, 2006]. Embedding the real-world objects with formal education can open up new possibilities for learning, where students create ideas, combine their expertise to design the products and share them for feedback or further development with wider audiences with help of new social technologies.

This paper focuses on design-oriented pedagogy that connects learning in formal, non-formal and informal settings. In the first part of the paper, the theoretical framework and design principles of the pedagogy as well as a description of its expected application will be presented. Then, examples of it's application and evaluation through design experiments are presented, and the future directions are discussed.

2 The framework for a design-oriented pedagogy

For most of the twentieth century, school education has been viewed as a process of transferring information from higher authority down to the students, and learning, as a series of steps to be mastered [Thomas and Brown, 2011]. However, considering the challenges we face in the twenty-first century and the situations we encounter in our lives, it is a question of wholes instead of elements or parts. Consequently, we should make learning whole and engage students in a collaborative pursuit of varying complex and multifaceted problems that often stem from outside educational institutions and, thereby, break the epistemic boundaries of school learning [Hakkarainen et al. in press, Perkins, 2009]. Most of challenges cannot be fully solved based on only the expertise of one domain; for that we need a group of engaging people who come from different backgrounds and possess diverse expertise (Communities of Interests, see [Fischer and Redmiles, 2008]). Complex challenges have no single solution; instead, they invite people to collaboratively design and redesign solutions from various perspectives.

Design is a social process and a core human activity [Roth, 1998]. It is generally considered to be a complex form of an iterative problem-solving process [Seitamaa-Hakkarainen et al. 2010]. It can be defined as a practice of cultural reproduction that provides more opportunities for people to participate in activities of cultural creation. Design is inherently multidisciplinary, and the process of design emerges through the co-creation of objects, narratives, identities and shared social understanding [Balsamo, 2010, Jenkins et al. 2008].

Learning to collaborate and connect through technology is an essential skill and competence that future societies will expect from its people [Binkley et al. 2011]. At this point, many researchers like to discuss twenty-first-century skills, such as being able to communicate and collaborate to solve complex problems, being able to adapt and innovate in response to new demands and changing circumstances, and being able to use technology to create new knowledge and expand human capacity and productivity [Binkley et al. 2011]. In order to make our schools and other learning institutions capable of functioning according to present-day challenges, new educational practices are clearly required.

Learning by designing [Hennessy and Murphy, 1999, Kodoner, 2002, Roth, 1998, Seitamaa-Hakkarainen et al. 2010] has been regarded as an instructional approach that can be appropriate in knowledge creation, because it provides opportunities to work with complex design tasks within authentic and meaningful learning contexts [Kangas et al. 2011, Seitamaa-Hakkarainen et al. 2010]. The design process has a cyclical and iterative nature; design solutions arise from a complex interaction between conceptualisation, visual sketching, construction of materially embodied artefacts and explorations in which design constraints and ideas are redefined [Hakkarainen et al. in press].

A ‘design-oriented pedagogy’ contains elements about learning by designing, but instead of construing artefacts, the emphasis is more on working with knowledge that is embedded or bound with physical objects and artefacts. Real-life objects, for example, in museums and natural or cultural environments that offer exceptional opportunities to pursue and develop an interest with real-world phenomena, engage in inquiry and develop digital representations. Authentic objects are potential mediators of learning, because these local objects can mediate global phenomena and make them approachable. Following Thomas and Brown [Thomas and Brown, 2011], learning becomes inextricably bound with the context where knowledge is situated, in contrast to traditional ‘chalk and talk’ classrooms in which knowledge is abstracted from real-life situations. In a world where context is always shifting and being rearranged, ‘expertise’ is less about having a stockpile of information or facts and more about knowing how to find, evaluate, remix and redesign information on the given topic [Thomas and Brown, 2011]. Figure 1 illustrates the framework for the design-oriented pedagogy.

Figure 1: The framework for a design-oriented pedagogy

A design-oriented pedagogy is based on three pillars: participatory learning as a vital conception for learning, Internet as a technological infrastructure, and co-development as an instructional model and as a powerful social innovation that underlines pedagogical principles.

Participatory learning places emphasis on self-learning and participation in research and development communities. Internet, as a technological environment, can enhance collaborative learning and, on the other hand, form a basis for personal learning environments. The technologies that the students own, especially mobile phones, provide tools to support learning across different contexts and to collect various empirical data. Social media provides platforms for students to share, develop and organise knowledge and to collaborate within and outside the school community.

Co-development has been demonstrated as being a powerful social innovation in product and software development (co-development; see Open Source and Linux phenomenon). It can also serve as a pedagogical basis for learning institutions. Co-development enables participation in communities that can mediate those practices that their full members implement. It places the emphasis on the social character of learning and enables the participants to move from the periphery to the centre of the activities and gradually become full members of those communities (especially research and professional communities of practices).

The students' agency will resemble those of scientists, designers and architects in authentic contexts. Referring to students as 'architects' means, for example, that they participate in collaborative designing of spaces for learning and create innovative solutions within the constraints of the situation and context. When connecting ongoing research in education, students can as part of their own studies gather relevant material for the research and development work and, at the same time, participate in the study. In this way, it is possible to create temporary research and development communities, which, through inquiry-centred activities, mediate the action and thinking models that are specific to the representatives of the expert community in question. Design-oriented pedagogy is a kind of co-development process where people learn through their interactions and participation with others, in fluid relationships that are the result of shared interest [see Thomas and Brown, 2011].

The design process emphasises authentic, idea-centred activities in collaboration with and between peers and teams, ideally heterogeneous and multi-aged student groups with varying expertises. Here, the students are not just learning from one another, they are learning with one another [Thomas and Brown, 2011]. It involves collaborative working with knowledge and continually coming up with creative solutions to unexpected problems [see Enkenberg, 2001, National Education Technology Plan, 2010, Resnick, 2007]. The goal is to build learning paths that mediate the practices of professional or scientific communities, and enhance students' skills to work together with knowledge in a meaningful and transparent manner.

Design-oriented pedagogy encourages working with domain experts and participating in the activities of expert communities. However, the role of the external expert is not only to provide answers to what we know about the phenomenon to be studied. It is also important in mediating the thinking and action models typical of the expert and thus enable students to understand what expert knowledge is and how we get to know something. In this way, design-oriented pedagogy places the emphasis on the social character of learning and opens also possibilities to mediate the tacit knowledge of expert culture [see Thomas and Brown, 2011].

The role of the teacher in a design-oriented pedagogy is to act as a tutor, organiser and provider of social support, and to create an atmosphere that encourages students' collaborative activities and the design process. In this kind of learning community, the expertise and authority are dispersed rather than centralised, and members of the community have valuable expertise to share [Thomas and Brown, 2011]. The teacher is a member of the learning community and the students can also act as teachers or experts; moreover, the differences and diversity among students and other community members becomes its strength.

2.1 Learning objects as design tasks

In the recent decade, the concept of 'learning objects' has received remarkable attention and enthusiasm in educational and e-learning communities [Churchill, 2005, Jonassen and Churchill, 2004, Wiley, 2000]. However, researchers and educators have had difficulties in agreeing on a definition for a learning object [see Churchill, 2008, Cocharane, 2005, Wiley, 2000, Wiley and Edwards, 2002]. The question also remains how to define a learning object to serve a specific instructional model or learning goals.

For developing a model for a design-oriented, co-development learning process, activity theory provides us a conceptual framework to define the learning object.

According to activity theory, knowledge as well as learning and action are in close interaction, and learning and knowledge emerge from action. The three factors, subject, object and tool, are all essential here and constitute a system. The subject comprises the social arrangement whereby learners participate in the action [Jonassen, 2000, Roth and Lee, 2007]. Learners can act alone or in a group, although deeper learning results can be achieved when learners, the teacher and other community members construct their understanding together [Krajcik and Blumenfeld, 2006]. Then, learners can develop their understanding, based on their own interests in different knowledge areas and at the same time take responsibility for the division of expertise with other community members [Bielaczyc and Collins, 1999]. The real objects are representatives of the culture in question and communicate different phenomena. The real physical objects can be approached from different domain perspectives (e.g. technology, biology, history or economy) or from a special interest group (e.g. researcher, hobbyist or profession) and by using varying tools, which augment physical, cognitive or social activity.

People, objects and tools constitute an interacting system in the co-development of learning objects, to serve as representatives for the phenomenon in question. We define learning objects 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’. Proceeding of the co-development process of the learning object design is presented in [Figure 2].

The first level of the construction process is choosing the affordances, that is, identifying the phenomenon and selecting the real objects representing it. The phenomenon will be framed by choosing the domain perspective, examining reported research, selecting the tools and media, and undertaking case studies in nature or culture environments. The contextualisation of constructed learning objects involves organisation and elaboration of the design resources, technical implementation, and designing of the scaffolds for future use, such as agency, guidelines, tags, and information resources. When learning is taking place from and with constructed learning objects, the process is reversed.

Social media provides new means for organise people’s joint efforts for developing artefacts and practices, and is a new form of mediation [Paavola et al. in press]. In developing learning objects, one can construct different kinds representations of physical objects (e.g. video clip, audio, drawing, map, picture or textual information) by using students mobile or smart phones. The various mobile technologies provide great opportunities for the collection of empirical data and transform the ideas of students into digital representations that can be jointly shared, discussed and further developed within the community.

The learning object can be shared in a chosen environment (e.g Wiki, YouTube) and may serve as an object of learning for others as well as for people outside the educational institution. However, the learning object itself is not usually open for editions, modifications or further development, like for example, the articles of Wikipedia. In Wikipedia, anyone can modify or make changes to chosen content, and what content remains usually depends on experienced editors and published reliable sources like academic and peer-reviewed publications. A single learning object is not designed to provide all the right answers or a comprehensive description of certain phenomena, but several learning objects together can offer different kinds of perspectives and interpretations about it. Therefore, the learning object combines different individual perspectives of the phenomena and can make learning whole in a new manner.

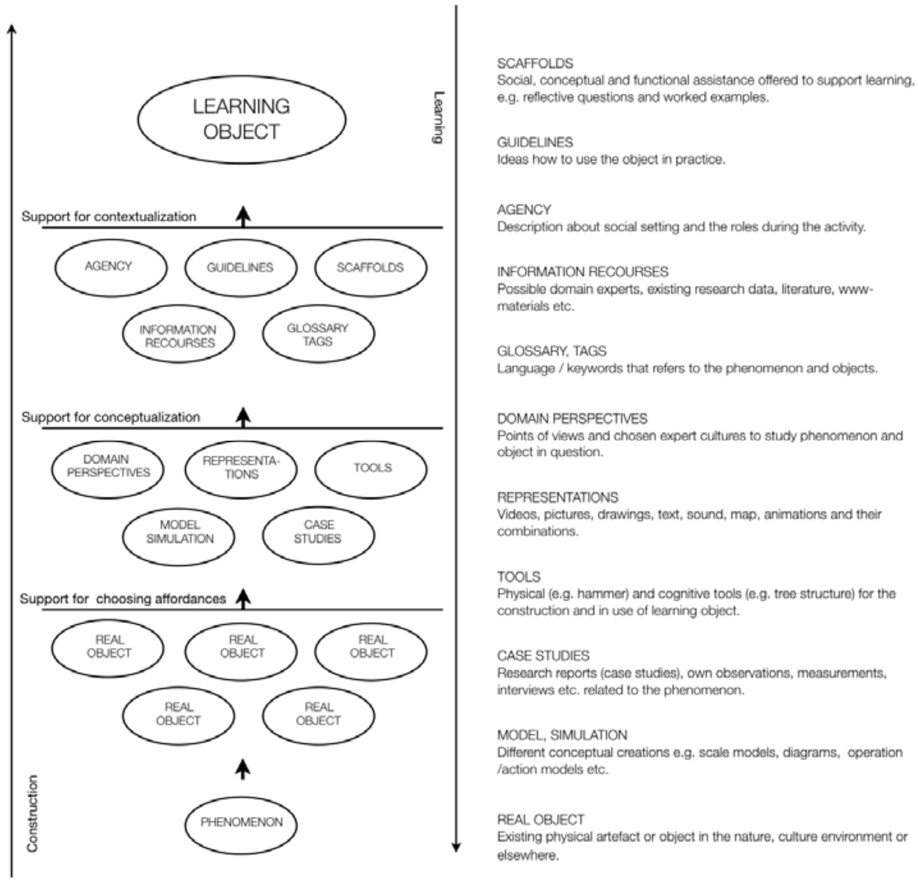


Figure 2: Procedural model for learning object design

2.2 An instructional model for the implementation of a design-oriented pedagogy

Based on the abovementioned viewpoints, the instructional model for a design-oriented pedagogy and related dimensions of learning environment are presented in [Figure 3].

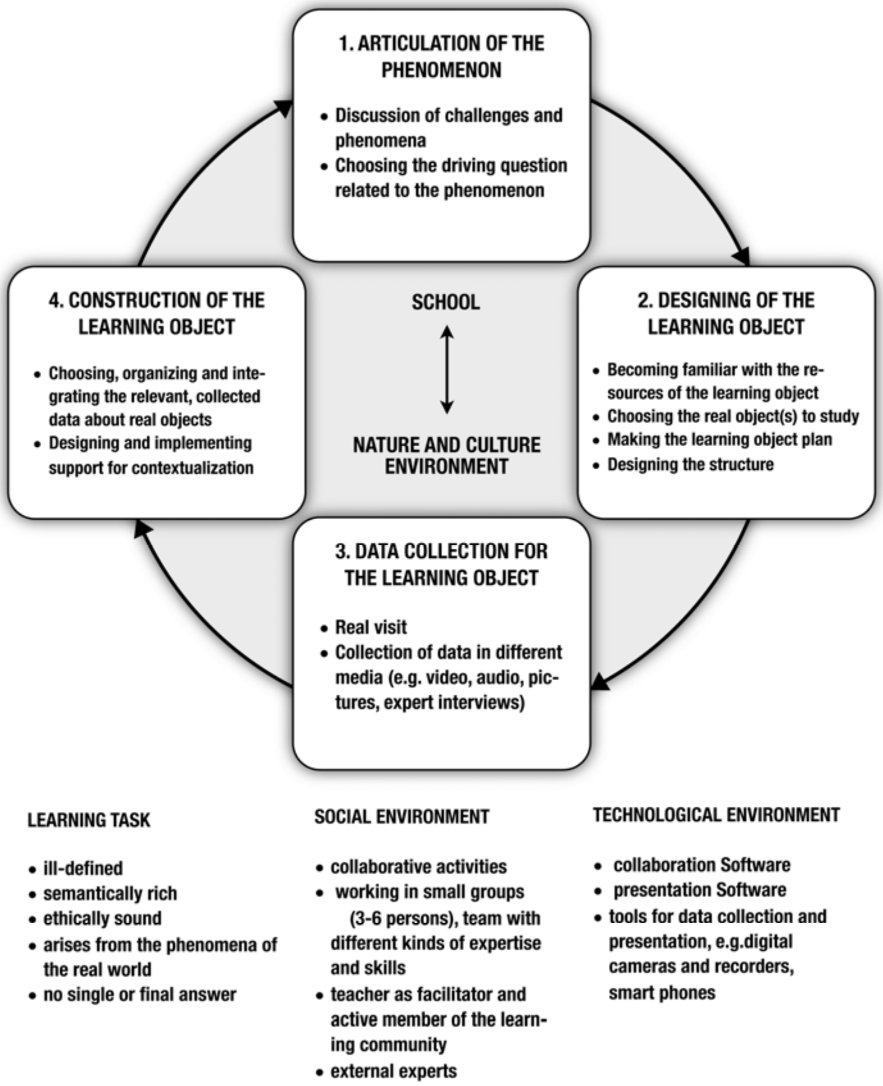


Figure 3: A proposed instructional model for a design-oriented pedagogy

In practice, the learning process is divided into four main phases, which partly take place at school, partly in the real environment and partly in the virtual environments [see Fig. 3]. The process usually begins at school, where students together with the teachers prepare the project by formulating their own object of interest, a mutual open challenge to be investigated. The open learning task is in essential role, because it connects with students' out-of-school experiences, make them meaningful and as resources for learning object design.

When the common challenge is articulated and the phenomena are chosen, the next task is to approach the common theme from the direction of the students' own research perspectives, research objects, methods and detailed research questions. The students are expected to choose the real object in the natural or cultural environment that mediates the phenomenon and provides answers to the proposed related complex questions.

Design is followed by the documentation of the learning objects and the students' travel to the natural or cultural environment to study real physical objects, interact with experts and collect different kinds of design resources by using various technologies [see Fig. 1]. The final phase is to organise and process the collected material in the chosen environment as a learning object, and design the support for contextualisation [see Fig. 2].

In the application of the model, the following principles will be highlighted:

- Anchoring the learning process on learners' ideas, thoughts, conceptions and interpretations about the research questions to be investigated (epistemological principle)
- Working with objects that represent the phenomenon and applying physical and cognitive tools (ontological principle)
- Developing knowledge by collaborative designing (learning principle)
- Using learners' possessed technologies in collecting empirical data (technological principle)
- Placing emphasis on affording learning resources, guiding and supporting the learning process (teacher's agency)
- Addicting and orienting learners by driven questions and whole tasks (instructional perspective)

3 The development, implementation and evaluation of a design-oriented pedagogy

Several researchers [Brown, 1992; Collins et al. 2004, Sandoval and Bell, 2004] have pointed out the difficulties of translating theoretical insights into educational practice. Thus, an increasing number of educational studies utilise the 'design-based research' approach, which focuses on theory-driven designing to generate complex interventions (e.g., learning environments) that also contribute to theory building and can be improved through empirical study [Design-Based Research Collective, 2003, Sandoval and Bell, 2004, Wang and Hannafin, 2005]. Following the principles of design-based research, the model of design-oriented pedagogy has been tested and validated in several design experiments during the last seven years with learners' groups of different backgrounds.

The development of a design-oriented pedagogy has been an iterative process where the model has been evaluated from multiple perspectives and with mixed method strategies [Johnson and Onwuegbuzie, 2004]. The focus has been 'the development of students' theoretical and conceptual understanding in design-oriented activities', second, 'how students experience and engage themselves in design-oriented learning' and, third, 'emerged social organization during the learning processes'. The fourth study pertains to teachers' thoughts about the pedagogy and its usability'. Next, the design experiments and evaluation of the model are briefly introduced.

3.1 Design experiment 1: The Ice Age project

The purpose of the first design experiment was to determine the possibilities and challenges that emerge when the natural or cultural environments that lie outside the school constitute the main context of learning projects [Liljeström et al. in press]. The focus of the experiment was to investigate the development of students' theoretical and conceptual understanding in authentic, project-based learning.

The 'Ice Age project', was implemented in 2005 with elementary school students (*N* = 17, five of whom were older students and twelve who were younger). The Ice Age project was a long, authentic learning project (three months) in a small, multiage rural school, where the natural environment surrounding the school comprised the main context. The applied instructional model emphasised learning by collaborative design [see Harel and Papert, 1991, Roth, 1998] and was based on principles of authentic learning [see Herrington et al. 2003]. The older students received an open-ended learning task to design and implement instruction about the Ice Age for their younger fellow students. The role of the teacher was to organise resources and the learning environment and anticipate unforeseen events in ways that supported the students doing authentic science activities. Mobile phones with GPS and location aware technology and applications served as tools for integrating the school with its outside environment and vice versa. The students also used digital cameras and different physical tools in data collection and shared their inquiries in web pages and a discussion forum.

Content analysis [see Chinn and Malhotra, 2002] of the data (video data, messages posted in the discussion forum, digital photos, web pages, the location aware data, pre- and post-tests, researcher's diary and group interviews) revealed that the complex, authentic and ill-structured learning task and emerged learning processes challenged students to work in an innovative and knowledge-productive manner, which seemed to generate creative thinking and high-quality conceptual models and to enhance cognitive processes resembling those of authentic science inquiry. More specifically, learning in the project seemed to develop students' explanations and theoretical understanding about the phenomena in question. [Liljeström et al. in press]. [Table 1] describes the relations between cognitive processes in authentic science inquiry and the respective learning activities that emerged in the Ice Age project.

One common criticism, often from teachers, is that these kind of authentic learning activities (e.g., project-based learning) are less efficient because the students may not be able to cover as much material as in a conventional, teacher-led study course. Kirschner et al. [Kirschner et al. 2006] argued that there appears to be no research supporting minimally guided instruction and that it may even have negative results. If we compare the results of the design experiment to those previously obtained, we would argue that authentic and project-based learning projects can challenge the students to collaboratively develop theoretical and conceptual understanding about the phenomena in question.

Cognitive processes in authentic inquiry [Chinn & Malhotra, 2002]	**Learning and authentic inquiry activities in the Ice Age project**
Generating research questions	Discussing in forums and classroom
Studying research reports *Designing studies* Selecting and controlling variables Planning procedures Planning measures	Reading books, Browsing the Internet, Studying maps, Discussing in forums and classroom, Designing field trips and studies
Making observations	Collecting data in nature (e.g. GPS data, photos, measurements, studies)
Explaining results Transforming observations Finding flaws Indirect reasoning Generalizations Types of reasoning	Designing and constructing scale models, Constructing web pages Arranging and organizing data, Designing and organizing and teaching activities, Presenting the results, Writing fictional stories, Solving mathematical problems
Developing theories Level of theory	Designing and constructing scale models, Designing and constructing web pages, Presenting the results
Coordinating results from multiple studies	Constructing web pages, Presenting the results

Table 1: Cognitive processes in authentic inquiry and respective learning activities that emerged in the Ice Age project

This experiment also showed that this kind of large-scale project can be carried out in schools, but the traditional school culture and the subject-based curriculum in Finland do not support it. However, the results of the study indicate the need to establish more economical ways to implement design-based learning and practice and to adopt more sophisticated tools to enhance the process of co-development.

3.2 Design experiment 2: Museum objects in learning

The importance of student engagement is recognised by many educators and researchers, as is the observation that far too many students are bored, unmotivated, and uninvolved, that is, disengaged from the academic and social aspects of school life [Appleton et al. 2008]. Theoretically, engagement is a complex concept that for instance Fredricks et al. [Fredricks et al. 2004] have defined as construct of three dimensions: emotional engagement, cognitive engagement and behavioural engagement. Emotional engagement is connected to feelings, values and interests and engagement to communal activities. Cognitive engagement includes higher-level thinking skills and learning strategies, while behavioural engagement can be regarded as commitment to carrying out the task or conform to the rules. However, behavioural, cognitive and emotional engagements are not isolated from each other, but are in a dynamic interaction. [Fredricks et al. 2004.]

Since the results of the first experiment brought up the need to re-model the learning process, we designed two models for learning to be evaluated in the second design experiment. The designing of the instructional models was based on learning by collaborative designing, semantically rich objects as the anchor of learning, and learning objects representing these objects. The learning projects differed from each other by the learning task and the instructional model; Model 1 focused on the construction of the learning objects, and Model 2 concentrated on the use of existing learning objects [see Fig 2]. In both projects, the personal learning environment consisted of the students' own cameras and video/audio recorders. The wiki environment was selected as the main platform for co-development.

In spring 2008, second-year student teacher (N=34) implemented two learning projects to a Finnish forest museum in addition to the lecture course. As the Ice Age project had demonstrated us the possibilities of enhancing cognitive processes in design-oriented activities, the focus of the second design [Vartiainen et al. 2009] was to investigate how the students experience and engage themselves in this kind of activity. To measure the students' engagement and experiences in relation to the instructional model, students were asked to participate in a questionnaire based on the dimensions of Fredricks et al construct [Fredricks et al. 2004], designed on a five-point Likert scale, and implemented after the learning process. To assess the students' experience of the learning projects, seven sum variables describing different dimensions of engagement were constructed from the separate test items.

The results of the study indicate that both projects emphasised communal activities in which the students were, in their opinion, engaged and that the learning projects were generally perceived as interesting. However, the non-parametric Kruskal–Wallis test showed that the groups differed statistically almost significantly, in emotional experience and cognitive processing. It seems that the construction of learning objects emphasised deeper cognitive processing, but partly at the cost of the emotions [Fig. 4].

The model for constructing the learning objects was new for the students; hence, they faced difficulties in perceiving the learning task and experienced some anxiety in the course of the project. [Vartiainen et al. 2009]. The relationship between cognitive processes and emotions is complicated. The learning should be challenging enough for the learners but not to produce too large emotional load or negative impact on self-efficacy [see Phelps, 2006]. We found that the instructional model of the construction of the learning object highly interesting. It led to diverse learning experiences and deep cognitive processes, but it required more scaffolds to facilitate the learning process of some students.

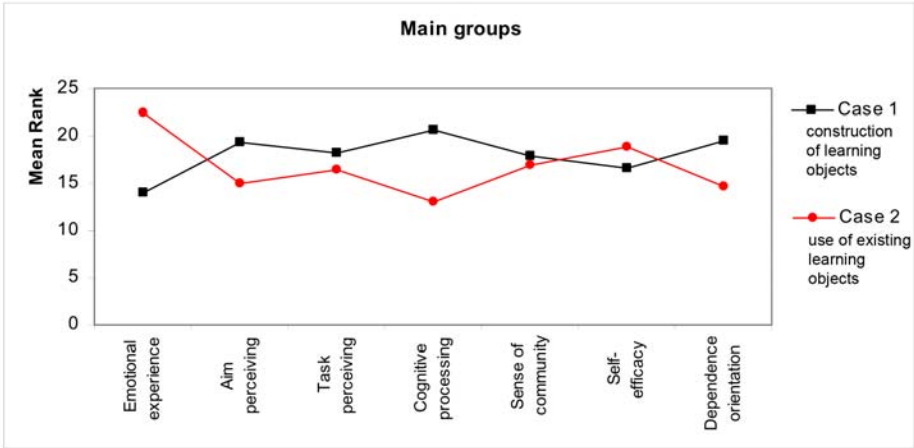


Figure 4: Engagement in learning projects. Source: [Vartiainen et al. 2009].

3.3 Design experiment 3: The Winter Fishing project

Based on the results of the previous design experiments, a more articulated procedural model for the learning object design [Fig. 2] and instructional model for the design-oriented pedagogy [Fig. 3] were developed. Since there seems to be a belief that this kind of authentic problem solving is only appropriate for students of a certain age or only for those who are already successful in school [see Kirschner et al. 2006], the focus of the third design experiment was to determine how a design-oriented pedagogy can work in a very heterogeneous group, where students of different ages and backgrounds study together.

The Winter Fishing project was implemented in spring 2009 with multiage (6-12 year old) rural school students (N = 32). The students received an open-ended learning task to 'design and implement study of winter fishing in small groups' (see attachment Learning process in Winter Fishing project). The groups produced seven different learning objects, and video served as main technological tool in the construction process. An example of the learning object 'How deep do the fish swim in the winter?' can be found on YouTube (http://www.youtube.com/watch?v=gVKeTflC5Qg). This learning object shows the development of process of science learning and how the children worked with their own ideas, interacted with experts and used different technologies to exercise choice, collaboration and reflection.

Social network analysis [see Kleiner, 2003, Marsden, 1990] was implemented to clarify the social networks during the collaborative activities that emerged in the learning project. Preliminary results of the social network analysis aimed to show how a versatile community of learners engaged with this kind of learning and how the students took on different types of roles in the project. One networking dimension was to determine who were the experts in the learning project. For that purpose, the students were asked to name those community members from whom they asked or received information, advice and guidance during the learning project [see Fig. 5).

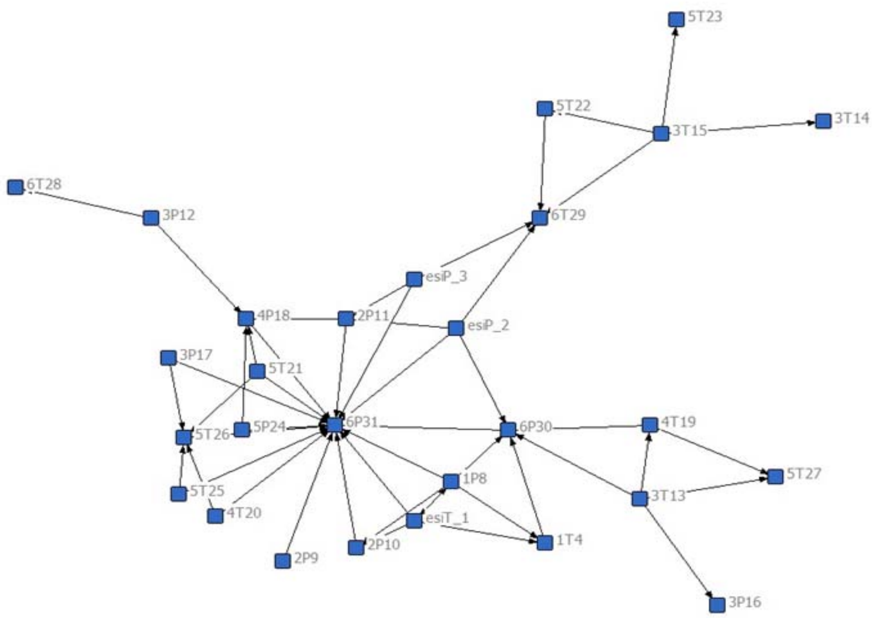


Figure 5: The social networking of expertise in the Winter Fishing project.

The preliminary results of networking of the learning community showed that one student, a boy from the sixth grade (6P31) in the middle of the social network, was an expert in this learning community. Many activities in learning project were driving by leadership of his expertise, and qualitative data complement picture of his actions and knowing. He was the one to whom others turned to and asked questions, he produced knowledge, taught his classmates and even teachers and researchers during the learning project.

The findings indicated that a design-oriented pedagogy provides novel possibilities for a heterogeneous learning community to exploit the existing knowledge and skills of its members. In contrast to traditional school lessons based on facts and isolated skills, the transparency of expertise became a cohesive force and provided possibilities to organise and develop collaborative practices. A design-oriented pedagogical model offers students the opportunity to choose topics and methods of learning based on their own interests, abilities and individual and community's learning needs [see Wenger, 1998] and enables them to move to the zone of proximal development [Vygotsky, 1978]. In addition, preliminary results of the study suggest that the students with special educational needs can also be successfully integrated with design-oriented learning, as compared to traditional teaching where teachers differentiate activities for learners with special needs.

3.4 Design experiment 4: Case Forest project

Implementing a new educational innovation in schools poses great demands on teachers [Zhang, 2010]. Therefore, our next step was to study how teachers who come from different schools and cultural contexts experience the instructional model of a design-oriented pedagogy. According to Zhang [Zhang, 2010], implementing new pedagogical and technological innovations faces various practical conditions and barriers in different classroom settings and cultural contexts. Teachers need to understand the contexts and identify challenges and barriers to develop effective strategies accordingly. The role of the teacher is not only to implement the external innovation, but by evaluating and deepening it, to also develop ownership over the innovation [Coburn, 2003, Zhang, 2010].

The fourth iteration of the study was carried out in the ‘Case Forest – pedagogic towards sustainable development’ (Comenius) project, in which the model was implemented in eight different countries; Finland (FI), Sweden (SE), Estonia (EE), Latvia (LV), Lithuania (LT), the Czech Republic (CZ), Slovakia (SK) and Bulgaria (BG) [Vartiainen and Enkenberg, 2011]. The research interest was to determine how participants of the project (N = 238) experience the design-oriented pedagogy and evaluate its usability from the perspectives of their own educational cultures.

In spring 2009, the project participants and two teachers from each country attended a workshop in Finland where participants implemented their own learning projects by designing learning objects from samples selected from the collections of the Finnish Forest Museum. In the model course, the participants brought their own cameras, laptops and mobile phones for data collection, and wiki served as the integrating environment. After the model course, a similar course was arranged in every country, and the project members and teachers attending the model course were responsible for it’s implementation in each country. The teachers were encouraged to define and recommend personal and social technologies that were available in their own country.

Project members were also required to write a report on their own teacher course and give an oral presentation about their experiences, in the final meeting held in Bulgaria in summer 2010. [Vartiainen and Enkenberg, 2011]. Qualitative analysis of the reports and presentations of each country indicate that the teachers found current school practices, belief systems and traditional models of teaching problematic for the implementation of design-oriented pedagogy [Table 2].

Further, lack of technology or teachers’ insufficient skills in using technology were often discussed as a challenge, while no other countries besides Lithuania mentioned the tools that the students already expertly use in informal settings. According to Scardamalia et al. [Scardamalia et al. 2011], in the twenty-first century, students use a wide range of technologies in their everyday lives and also bring these technologies to schools. However, often teachers do not take advantage of these technologies or use the skills and experiences that students bring with them as a way to further develop their twenty-first-century skills [Scardamalia et al. 2011].

COUNTRY	**CZ**	**EE**	**LV**	**SK**	**FI**	**LT**	**BG**	**SE**
Technological problems								
Lack of equipment		X	X			X		X
Teachers insufficient IT-skills			X	X				
Social problems								
Teachers attitudes towards new technology		X	X					
Teachers attitudes towards new pedagogical approaches		X	X	X		X		X
Attitudes of pupils, colleagues or principal					X	X		
Contextual problems								
Lack of financial resources	X	X	X			X		
Lack of time		X	X		X	X		X
Curriculum				X		X		
Political regulation of education	X		X					

(*) *Note that according to the report from Bulgaria, there were no problems using the methodology. In the presentation they mentioned "obligatory problems", but did not explain them further.*

Table 2: Problems in implementing the pedagogy, Source: [Vartiainen and Enkenberg, 2011]

Many teachers participating in the project also emphasised the possibilities that the design-oriented pedagogy creates for learning by making it interesting, meaningful and engaging for the students. The teachers also saw the pedagogy as one way to change the school practices and current models of education to meet future needs. However, it seems that current school culture (e.g. epistemological beliefs, attitudes, curriculum, classroom activities and assessment) and resources (e.g. financial resources, technological resources and time) are creating challenges and limitations for implementing the design-oriented pedagogy in schools, in collaboration with external organisations and experts. The preliminary results of the study reflect Zhang's [Zhang, 2010] argument that implementing new innovations provided by researchers is difficult, as the new practices are often assimilated into ongoing practice and are ritualised as surface procedures in implementation, without causing deep change. Successful and sustained innovation requires teachers to engage, re-think and deepen the underlying pedagogical principles and evolve new designs in their contexts with their students [Zhang, 2010].

4 Conclusions and discussion

The development of a design-oriented pedagogy through several design experiments has shown us the possibilities that the pedagogy creates for learning and also indicates challenges that future research might address. The first experiment demonstrated that a design-oriented pedagogy with open learning tasks encourages students to develop explanations and a theoretical understanding about the phenomena in question and this can lead to deep cognitive processing [Liljeström et al. in press]. Traditional education emphasises knowledge that is well defined and reduced into smaller subtasks and subskills. Usually, learning results are assessed at the end of the course, with the aim of evaluating if the goals have been achieved. A design-oriented pedagogy is not an orderly step-by-step process, but instead moves from teaching separate knowledge and skills towards making the learning whole. However, the knowledge and abilities to transfer knowledge and strategies to novel problems tend to emerge afterwards. Further research is required to establish how students at various ages achieve a deep understanding of domain knowledge and apply it in a given domain as well as in everyday activities once they leave the classroom [see Scardamalia et al. 2011].

The second experiment indicated that students find the construction of learning objects more engaging than the more traditional way of using learning objects that experts and teachers have produced. It appears that constructing learning objects challenges the students to work at the edge of their competence, but it can be demanding emotionally. As Bandura [Bandura, 1993] notes, personal accomplishments require not only skills but self-beliefs of efficacy to use them well. This suggests that teachers should recognise these emotions of learners in regard to different learning activities and scaffold them when needed. Further research is necessary to determine whether student engagement is maintained if design-oriented learning becomes a sustained practice.

The initial results of the third experiment suggested that a design-oriented pedagogy is suitable for heterogeneous learning communities, because it offers the possibility of appreciating the existing strengths of all students and developing them further. Learning by collaborative designing of a learning object is a continuous transfer from one space to another and at the same time connects something global, local and personal. As technology blurs the line between in- and out-of-school contexts, knowledge becomes a social product situated in the open world [Scardamalia et al. 2011]. The example of the learning object highlights how the ideas of the learners can and should be a part of constructing continuously growing knowledge and expertise around shared objects across spaces. Our observations encourages to trust in students' agency, where the learners draw on each other for ideas and resources that scaffold taking collective ownership over their own learning [see Scardamalia et al. 2011; Zhang, 2010]. However, further studies are required to better understand the existing social relationships that affect the community's work [Scardamalia et al. 2011].

In the fourth design experiment, the participating teachers coming from different educational backgrounds saw many learning possibilities, several possible future uses for the pedagogy, from kindergarten to university, and programs outside of formal education. On the other hand, the design-oriented pedagogy can be challenging for teachers, as it requires re-thinking of the teacher's agency. Moreover, the learning cultures and resources are different in these European countries, thus creating varying challenges for the teachers to implement and sustain a design-oriented pedagogy. When considering the lack of technology in schools, our experience encourages us to make more use of the technology that students already possess and know.

To facilitate the development of twenty-first-century skills, schools should make technologies available to all children (compare textbooks), especially to those who do not have access to it. However, the effects of technology depend not only on the equipment, but above all, on the pedagogy, which in many cases is more important than the technical features of the applied technology [Lehtinen, 2003]. Moreover, education reform must be systemic, not just technological, and it requires close association between research-based innovation and practice [Scardamalia et al. 2011]. In conclusion, based on our findings, we argue that a learning process that combines design thinking with project-based learning can be one effective approach to facilitating the development of twenty-first-century skills in students.

Acknowledgements

This study has been supported by the Doctoral programme for Multidisciplinary Research on Learning Environments (OPMON), Academy of Finland (under project no. 1217068) and Forest as a learning environment (University of Eastern Finland, under project no. 24403).

References

[Appleton et al. 2008] Appleton, J., Christenson, S. & Furlong, M. (2008). Student engagement with school: Critical conceptual and methodological issues of the construct. Psychology in the Schools, 45(5), 396-386.

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

[Bandura, 1993] Bandura A. (1993). Perceived self-efficacy in cognitive development and functioning. Educational Psychologist, 28(2), 117–148.

[Banks et al. 2007] Banks, J.A., Au, K.H., Ball, A.F., Bell, P., Gordon, E.W., Gutierrez, K.D., Heath, S.B., Lee, C.D., Lee, Y., Mahiri, J., Nasir, N.S., Valdes, G. & Zhou. M. (2007). Learning in and out of school diverse environments: Life-long, life-wide, life-deep. Report from the LIFE Center (The Learning in Informal and Formal Learning Environments Center and the Center for Multicultural Education), University of Washington, Stanford University and SRI International.

[Bielaczyc and Collins, 1999] Bielaczyc, K. & Collins, A. (1999). Learning communities in classrooms: A reconceptualization of educational practice. In C. M. Reigeluth

(Ed.), Instructional design theories and models: A new paradigm of instructional theory (pp. 269–292). Mahwah NJ: Lawrence Erlbaum Associates.

[Binkley et al. 2011] Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M. & Rumble, M. (2011). Defining 21st century skills. In Griffin, P., McGaw, B. & Care, E. (Eds.) Assessment and Teaching of 21st Century Skills (pp.17-66), New York: Springer.

[Brown, 1992] 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.

[Chinn & Malhotra, 2002] Chinn, C. A. & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. Science Education, 86(2), 175–218.

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

[Churchill, 2008] Churchill, D. (2008). Towards useful classification of learning objects. Education Technology Research & Development, 55(5), 479–497.

[Coburn, 2003] Coburn, C. E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. Educational Researcher, 32(6), 3–12.

[Cocharane, 2005] Cocharane, T. (2005). Interactive quicktime. Developing and evaluating multimedia learning objects to enhance both face-to-face and distance e-learning environments. Interdisciplinary Journal of Knowledge and Learning Objects, 1(1), 33–54.

[Collins et al. 2004] Collins, A., Joseph, D. & Bielaczyc, K. (2004). Design research: Theoretical and methodological issues. Journal of the Learning Sciences, 13(1), 15–42.

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

[Edelson and Reiser, 2006] Edelson, D. & Reiser, B. (2006). Making authentic practices accessible to learners. In K. Sawyer (Eds.), The Cambridge handbook of the learning sciences (pp. 335–354). Cambridge: Cambridge University Press.

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

[Fischer and Redmiles, 2008] Fischer, G. & Redmiles, D. (2008). Transdisciplinary education and collaboration. Meeting of the Human Computer Interaction Consortium (HCIC) February 2008. Frasier, CO.

[Forman and Sink, 2006] Forman, E. & Sink, W. (2006). Sociocultural approaches to learning science in classrooms. Final Draft of a Report to the National Research Council Committee on Science Learning K-8. University of Pittsburgh 1/16/2006. Retrieved October, 2011 from http://www7.nationalacademies.org/bose/Forman_Commissioned_Paper.pdf

[Fredricks et al. 2004] Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. Review of Educational Research, 74, 59 – 109.

[Harel and Papert, 1991] Harel, I. & Papert, S. (1991). Software design as a learning environment. In I. Harel & S. Papert (Eds.), Constructionism (pp. 41–84). New Jersey: Ablex Publishing Corporation.

[Hakkarainen et al. in press], Hakkarainen, K., Paavola, S., Kangas, K. & Seitamaa-Hakkarainen, P (in press). Socio-cultural perspectives on collaborative learning: Towards collaborative knowledge creation. A draft of a book chapter submitted to be published in C. Hmelo-Silver, A. O'Donnell, C. Chan & C. Chinn (Eds.), The International Handbook of Collaborative Learning. Retrieved 6th Desember, 2012, from http://utu.academia.edu/KaiHakkarainen/Papers/316810/Draft_of_Hakkarainen_K._Paavola_S._Kangas_K._and_Seitamaa-Hakkarainen_P_submitted_Sociocultural_perspectives_on_collaborative_learning_Towards_collaborative_knowledge_creation

[Hennessy and Murphy, 1999] 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 et al. 2003] Herrington, J., Oliver, R. & Reeves, T. C. (2003). Patterns of engagement in authentic online learning environments. Australian Journal of Educational Technology, 19(1), 59–71.

[Jenkins et al. 2008] 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: John D. and Catherine T. MacArthur Foundation. Retrieved 3th Desember, 2012, from http://www.nwp.org/cs/ public/print/resource/2713.

[Jonassen, 2000] Jonassen, D. (2000). Learning: as activity. The meaning of learning project. Learning development institute. Retrieved 25th January, 2011, from http://www.learndev.org/.

[Jonassen and Churchill, 2004] Jonassen, D & Churchill, D. (2004). Is there learning orientation in learning objects? International Journal of E-Learning (April-May) 32–42.

[Johnson and Onwuegbuzie, 2004] Johnson, R. & Onwuegbuzie, A. (2004). Mixed methods research: A research paradigm whose time has come. Educational Research, 33(7), 14–26.

[Kangas et al. 2011] 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, International Journal of Technology and Design Education (11 May 2011), pp.1-18.

[Kirschner et al. 2006] Kirschner, P. A, Sweller, J. & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. Educational Psychologist, 41(2), 75–86.

[Kleiner, 2003] Kleiner, A. (2003). Karen Stephension's quantum theory of trust. Retrieved 4th February, 2009, from http://www.well.com/~art/PDF%20Files/s%Bb42002cm.pdf.

[Kodoner, 2002] 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.

[Krajcik and Blumenfeld, 2006] 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.

[Lehtinen, 2003] Lehtinen, E. (2003). Computer supported collaborative learning: An approach to powerful learning environments. In E. De Corte, L. Verschaffel, N. Entwistle & J. Van Merriëboer (Eds.), Unraveling basic components and dimensions of powerful learning environments (pp. 35–53). Amsterdam: Elsevier.

[Liljeström et al. in press] Liljeström, A., Enkenberg, J. & Pöllänen, S. (in press). Making learning whole: an instructional approach for mediating the practices of authentic science inquiries. Cultural Studies of Science Education. Online First June 2012. DOI 10.1007/s11422-012-9416-0

[Marsden, 1990] Marsden, P. V. (1990) Network data and measurement. Annual Review of Sociology, 16, 435–463.

[National Education Technology Plan, 2010] National Education Technology Plan. (2010). Learning powered by technology. Retrieved 7th November , 2011, from www.ed.cov/technology/netp-2010.

[Paavola et al. in press] Paavola, S., Engeström, R. & Hakkarainen, K. (in press). Trialogical approach as a new form of mediation. In A. Morsh, A. Moen & S. Paavola (Eds.), Collaborative knowledge creation: Practices, tools, and concepts (pp. 9–23).

[Phelps, 2006] Phelps, E. (2006). Emotion and cognition: Insights from studies of the human amygdala. Annual Review of Psychology, 57, 27–53.

[Perkins, 2009] Perkins, D. N. (2009). Making learning whole: How seven principles of teaching can transform education. San Francisco: Jossey-Bass.

[Resnick, 2007] Resnick, M. (2007). Sowing the seeds for a more creative society. Learning and Leading with Technology (December 2007), 18–22.

[Roth, 1998] Roth, W.-M. (1998). Designing communities. Dordrecht, Netherlands: Kluwer Academic Publishers.

[Roth and Lee, 2007] Roth, W.-M. & Lee, Y. J. (2007). “Vygotsky’s neglected legacy”: Cultural-historical activity theory. Review of Educational Research, 77(2), 186–232.

[Sandoval and Bell, 2004] Sandoval, W. A. & Bell, P. (2004). Design-based research methods for studying learning in context: Introduction. Educational Psychologist, 39(4), 199–201.

[Salomon, 1997] Salomon, G. (1997). Distributed cognitions: Psychological and educational considerations. Cambridge: Cambridge University Press.

[Scardamalia et al. 2011] Scardamalia, M., Bransford, J., Kozma, R. & Quellmalz, E. (2011). New assessments and environments for knowledge building. In Griffin, P., McGaw, B. & Care, E. (Eds.) Assessment and Teaching of 21st Century Skills (pp.231-300), New York: Springer.’

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

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

[Vartiainen and Enkenberg, 2011] Vartiainen, H. & Enkenberg, J. (2011). Enlargement of Educational Innovation: An Instructional Model of the Case Forest Pedagogy. Proceedings of the 4th International Network-Based Education 2011 Conference The Social Media in the Middle of Nowhere. University of Lapland Publications in Education 25, pp. 76-86.

[Vartiainen et al. 2009] Vartiainen, H. , Enkenberg, J. & Liljeström, A. (2009). Oppimisen kokeminen ja sitoutuminen oppimisaihioiden ja tutkimusprosessin suunnittelua painottavissa oppimisprojekteissa. Interaktiivinen tekniikka koulutuksessa 2009 -konferenssin tutkijatapaamisen artikkelit. Tampere University Press, Interaktiivisen median tutkimuksia - Research of Interactive Media 2, pp. 46-57.

[Vygotsky, 1978] Vygotsky, L. S. (1978). Thought and language. Cambridge: MIT Press.

[Wang and Hannafin, 2005] Wang, F. & Hannafin, M. (2005). Design-based research and technology-enhanced learning environments. Educational Technology Research and Development, 53(4), 597–621.

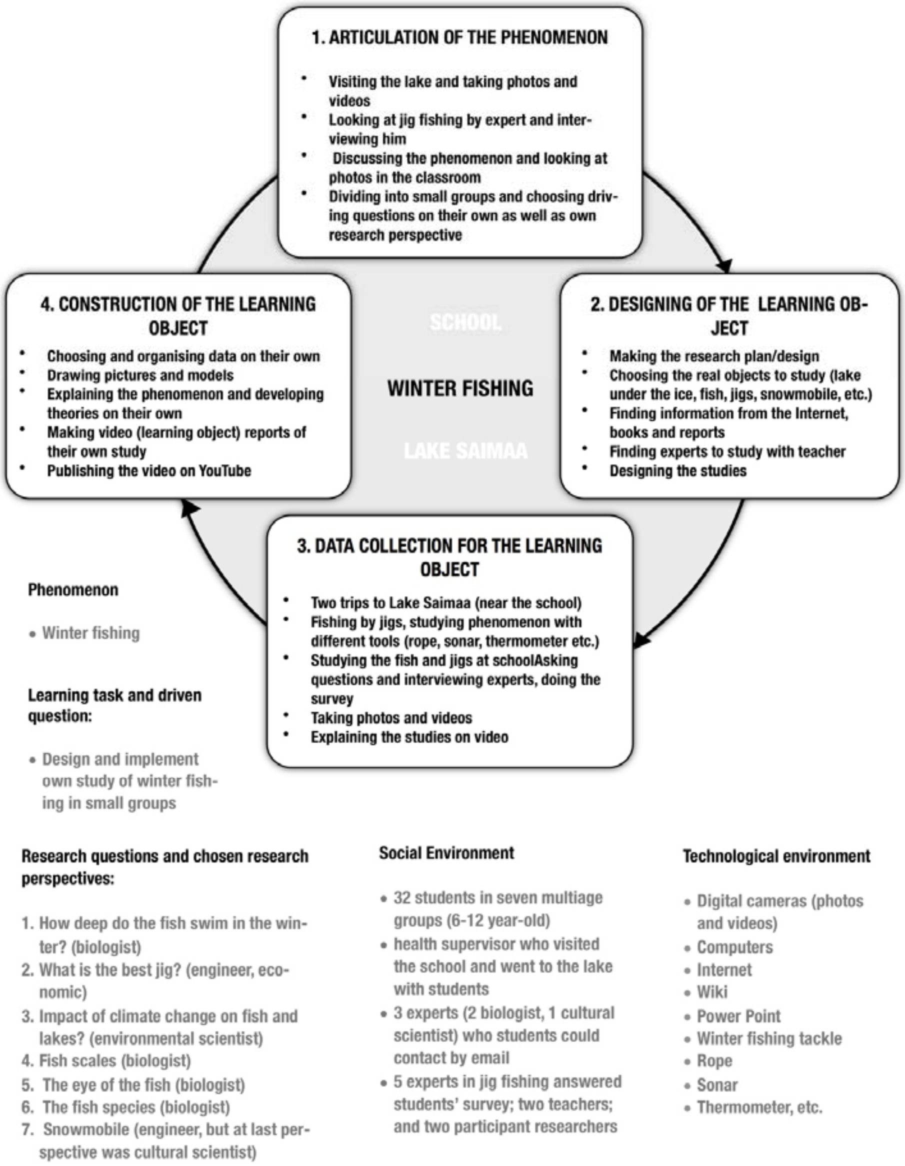
[Wenger, 1998] Wenger, E. (1998). Communities of practice: Learning, meaning, and identity. New York: Cambridge University Press.

[Wiley, 2000] Wiley, D. (2000). Connecting learning objects to instructional design theory: A definition, metaphor, and a taxonomy. In D. A. Wiley (Ed.), The instructional use of learning objects. Retrieved 15th August, 2011, from http://reusability.org/read/chapters/wiley.doc.

[Wiley and Edwards, 2002] Wiley, D. & Edwards, E. (2002). Online self-organizing social systems: The decentralized future of online learning. Quarterly Review of Distance Education, 3(1), 33–46.

[Zhang, 2010] Zhang, J. (2010). Technology supported learning innovation in cultural contexts. Educational Technology Research and Development, 58, 229–243.

Attachment 1: Learning process in The Winter Fishing project



An example of the learning object, co-developed in this project and in the framework of the pedagogical model, can be found on YouTube (http://www.youtube.com/watch?v=gVKeTflC5Qg). In this case, the learning object has been entirely produced by these primary school children in a small village school in Finland.