Collaborative Design Practices in Technology Mediated Learning

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RESEARCH

Abstract

The present article examines how practices of computer-supported collaborative designing may be implemented in an elementary classroom. We present a case study in which 12-year-old students engaged in architectural design under the guidance of their teacher and a professional designer. The students were engaged in all aspects of design processes, such as analysing the design of existing houses, analysing the building site, determining building volume, design facades, and floor plans; they formed seven teams, each of which had its own house to design. The data-analysis relied on the Knowledge Forum database, consisting of students' notes, pictures, sketches, and photos. The participants' quantitative contributions to the database were analyzed with Analytic ToolKit which underlies Knowledge Forum. A qualitative content analysis was performed to the KF notes produced by the student teams; a theory and data-driven approach for categorizing the content of the notes was employed. The results revealed that the student teams considered various design constraints and familiarized themselves with their own building site and regulations regarding their permitted building volume. They constructed environmental models and scale models, and made the calculations of gross floor volume; scale drawings were inserted to KF's Environmental Model view as pictures and texts. The results indicated that parallel working with conceptual (design ideas) and material artefacts (architectural models, prototypes of apartments, figures) supported one another. The intent was that involving students in modeling practices would help them build domain expertise, epistemological understanding, and skills to create and evaluate knowledge. Further, implications for designing technology-mediated collaborative design processes are discussed.

Key words

design project, design and technology education, Learning by Collaborative Designing (LCD), technology-mediated learning

Introduction

Design and technology education (D&T) has a special importance in promoting human creativity, particularly when conceptual and material aspects of the process reciprocally support one another (Kangas et al., 2007; Seitamaa-Hakkarainen et al., 2010). Rather than merely emphasizing abstract scientific inquiry in school learning, designing can be considered as an archetypical form of innovative learning, where one has to learn not only what is already known, but also go beyond what is given and learn the potentials in a situation for creating something new. Learning by designing is usually connected to technological design (Kolodner et al., 2003; Roth, 1996), designing artefacts (Lahti et al., 2004), learning science (Fortus et al., 2004; Roth, 1998), or their combinations (Hansen, 2009; Kangas et al., 2007).

The present article examines how practices of computer supported collaborative designing may be implemented in an elementary classroom. We describe the "Architecture Project", where elementary students designed apartment buildings with the help of a professional designer. The project was based on the following ideas: 1) intensive collaboration between the teacher, the designer, and researchers, 2) integration of many school subjects, such as history, mathematics, mother tongue, biology, geography, visual arts, and design & technology education, for solving a real-world architectural problem, 3) engaging students in sustained effort of building knowledge regarding the themes, and 4) integrating conceptually-driven (minds on) inquiry with a materially embodied one (hands on). During the whole project, a technology enhanced learning environment, Knowledge Forum, was used.

The ideas behind the Architecture Project rest upon the *Learning by Collaborative Designing* – model (LCD model, Seitamaa-Hakkarainen et al., 2005; 2010), which is a pedagogical model that assists teachers and students who are engaging in design activities. Our aim is to analyze how the pedagogical practices supported by the LCD model (to be explained below) is implemented in an elementary classroom. We address the following specific research questions:

(1) How did the ideas of the LCD model become actualized in practice during the Architecture Project? What kind of design learning processes emerged during the project?
(2) What was the role of conceptual and material artifacts in designing?
(3) What was the role of the technology enhanced learning environment?

In the following, we will first introduce the Learning by Collaborative Designing model and consider the role of material mediation in design learning. Then, we describe our empirical study and discuss the results in the light of the recent research in Design and Technology Education.

Learning by collaborative designing

The complex and multidisciplinary nature of design problems calls for intensive collaboration across different domains. The activities of those in the design professions are often based on teamwork combining several fields of distributed expertise (Chiu, 2002; Perry and Sanderson, 1998). Consequently, the use of collaborative settings (e.g., Drain, 2011; Hennessy and Murphy, 1999; Hong et al., 2011; Rowell, 2002) and the role of virtual learning technology in the area of design and technology education has increased (e.g., Karakaya and Senyapili, 2007; McCormick, 2004). 'Collaboration' refers to a process in which students actively work together in creating and sharing their design ideas, deliberately making joint decisions and producing shared design objects, constructing and modifying their design solutions, as well as evaluating their outcomes through discourse (Hennessy and Murphy, 1999). We agree with many recent researchers that the D&T context provides a potentially rich environment for collaborative learning and designing (Carroll et al., 2010; Hennessy and Murphy, 1999; Murphy and Hennessy, 2001; Rowell, 2002). Students' experiences of collaborative designing in educational settings appear to promote practices of collective elaboration of design ideas (Drain, 2011; Fisher et al., 2005; Murphy and Hennessy, 2001) as well as the implementation of these ideas in the actual design of artefacts.

The pedagogical models that have been widely adopted in design education are problem-based learning (Hill and Smith, 2005) and project-based learning (Carroll et al., 2010; Drain, 2011). These teaching and learning methods have mainly been used in face-to-face and hands-on situations. Drain (2011) has noted that project based teaching can place extra demands on the teacher and there is special need for pedagogical models that support teaching in design and technology settings. Learning by Collaborative Designing (LCD) is a pedagogical model that has been developed to guide and facilitate students' collaborative design processes in technology enhanced learning (Kangas et al., 2007; Seitamaa-Hakkarainen et al., 2010). The model emphasizes open-ended design tasks and collaborative interaction within and between peers or teams; between students and the teacher and/or external domain experts. It guides all participants to take part in deliberate advancement of ideas, and highlights the role of physical artifacts, material objects, and abstract models as essential aspects of the design process.

The LCD model represents designing as a spiral and iterative process. Instead of describing rigidly specified design stages (see also Carroll et al., 2010; Fortus et al. 2004; Kolodner et al. 2003), the model illustrates the relations between the elements of collaborative design processes (see Figure 1). The idea of the model is that all

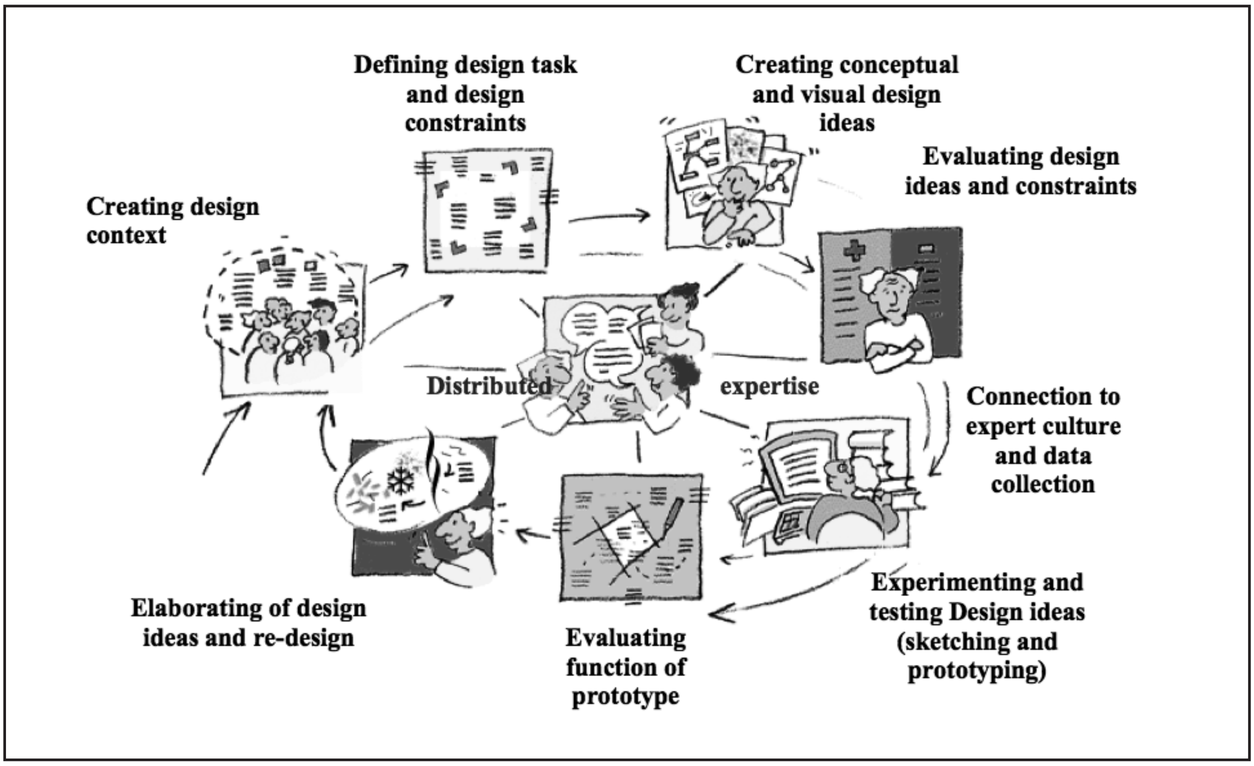

Figure 1. Learning by Collaborative Designing (LCD) model

participants are working to develop a shared design object by sharing their expertise socially. The model consists of the following partially overlapping phases: 1) creating design context, 2) defining design task and related design constraints, 3) creating conceptual and visual design ideas, 4) evaluating design ideas and constraints, 5) experimenting and testing design ideas by sketching, modeling, and prototyping, 6) evaluating functions of prototypes, and 7) elaborating design ideas and redesigning.

The design process starts with all participants performing a joint analysis of the design context and design task. In this phase, teacher or external domain experts have an important role to help students to define the diverse cultural, social, psychological, functional and emotional aspects essential to the design of the product. During the outlining of the design constraints, there are sometimes conflicting issues that have an effect on the design process and its requirements that need to be taken into consideration. By acquiring deepening knowledge, sharing that knowledge socially, producing varying design ideas and evaluating those ideas, participants move the design process forward cyclically. Thus, constant cycles of idea generation and testing of design ideas by visual modelling or prototyping, characterize the process.

Mediating artefacts in designing

Collaboration with peers and other participants of the design process, as well as interaction with diverse mediating artefacts, have been found to be important in designing (Hennessy and Murphy, 1999; Roth, 1996; Rowell, 2002). Designing cannot be reduced to merely playing with ideas; in order to understand and improve the ideas in question, they have to be given a material form by means of practical exploration, drawing, prototyping, and manufacturing (Hope, 2005; Rowell, 2002; Welch et al. 2000). In the context of D&T, the interaction with tools, concrete objects and materials is a central aspect and offers a potentially supportive environment for vital collaborative designing, i.e., for developing shared objects and understanding (Carroll et al., 2010; Hennessey and Murphy, 1999; Johansson, 2006; Murphy and Hennessy, 2001; Rowell, 2002). Through social interaction and visualization, design ideas, proposed solutions, and decisions are made verbally and visually explicit and visible, and joint decisions can be made. Involving students in modeling practices can help them build domain expertise, epistemological understanding, and skills to create and evaluate knowledge (Schwartz et al., 2009).

A review of the research examining the role of sketching for design professionals (Welch et al., 2000) shows that sketching has a crucial role in generating, developing, and communicating ideas; it is both a powerful form of thinking and the fundamental language of design. Professional design activities rely on the use of various tools and design representations, such as sketches, models and notes (Al-Doy and Evans, 2011; Goel, 1995). Through the process of externalization and collaborating around design representations, the first vague design ideas are transformed into further articulated and more determined ideas, to the explicit design alternatives, and finally, externalized and objectified as materially embodied design artifacts (Al-Doy and Evans, 2011). Numerous external representations (graphical and physical) in various phases of the design process provide different kinds of prompts to test the design ideas (Al-Doy and Evans, 2011). In D&T school settings, material artifacts and tools have a central role in mediating the learning process; the design process involves parallel work through conceptual reflection and material implementation. However, research has shown that novice designers rarely use two-dimensional models, i.e., sketching, but tend to move immediately to three-dimensional modeling (Hope, 2005; Rowell, 2002; Welch, 1998). Furthermore, when sketching or other forms of modeling occurs, they are primarily used for illustrative or communicative purposes, hence reducing the epistemic richness of the practice (Schwartz et al., 2009).

Consequently, sketching is central, in our view, to developing capability in D&T education. In the context of D&T education, the interaction with two- and three-dimensional models offers students direct possibilities to explore and evaluate a proposed solution's form and function (Hennessy and Murphy, 1999; Rowell, 2002; Welch et al., 2000). In the early stages of designing, sketching helps to define and clarify the task, and explicate the needs constraining the task. It also enables and encourages the students to play with ideas, which is essential in creative problem solving. In designing, students are concerned with the usefulness, adequacy, improvability, and developmental potential of ideas (Bereiter and Scardamalia, 2003) and develop knowledge and skills to model, design and construct ideas into physical artefacts. Furthermore, sketching facilitates the evaluation of ideas and elaboration of the design task. In addition, sketching can be used to communicate one's design ideas with others; it also enables those others to contribute to the ideas (Al-Doy and Evans, 2011; Welch et al., 2000). In other words, various design representations allow students to interact with one another through the design object itself, as collaborating participants' activities are mediated and made visible through them.

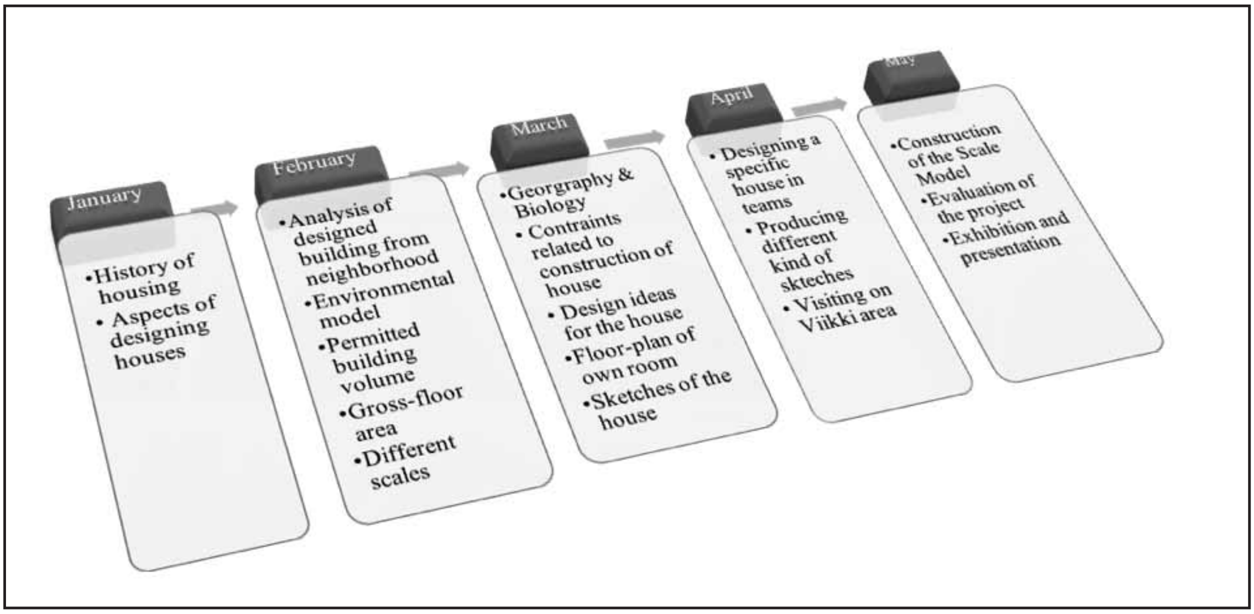

Figure 2. Main activities during each month of the Architecture Project

Method

Participants and the setting of the study

The Architecture Project was designed together with a class teacher, and it took place in her classroom in an elementary school, located in a middle-class suburb in Helsinki, Finland. The students (N=29) were 6th graders, 12 years old, and it was their final year of elementary school. The project lasted 19 weeks and took approximately 45 lessons, about 2-3 hours a week. The designer was present in the classroom across the entire time of the project, representing expertise in architectural design. The interaction between him and the students varied from whole-class discussions to coaching of the students' small-team discussions. Figure 2 represents the main activities during each month of the project.

In the classroom, there were ten computers, including the teacher's own computer and data projector. The technical infrastructure of the Architecture Project was provided by Knowledge Forum (KF), a networked learning environment based on knowledge building pedagogy (Bereiter, 2002; Bereiter and Scardamalia, 2003; Scardamalia and Bereiter, 2006). The central aspect of KF is a common working space for the students; a database that consists of knowledge (texts and graphics) produced by the students and teachers. The database is organised around views. A view is a kind of visually organized representation of a selected part of the database, and it may contain thematically connected textual notes, drawings, photographs, and links to other views (shown as an arrow).

During the Architecture Project, the students worked in 7 teams (4-5 students in each), building knowledge in each teams' own KF view as well as in the shared views of the whole class. Figure 3 represents one of the shared views, the project's Welcome view, representing the building site of the project.

Figure 3. The Welcome view in the Architecture Project's KF database

Method of data analysis

Our analysis of the Architecture project relies only on the project's KF database, consisting of notes, pictures, sketches and photos posted by participants. Firstly, the participants' quantitative contributions to the database were analyzed using Analytic ToolKit, which underlies Knowledge Forum. It reveals the frequency of computer posting (i.e., notes, views, rise aboves, build-ons), as well as note-reading activity. We analyzed how the participants created and used the KF views across various activities of the project through the following categories: (1) name of the worked view, (2) number of students' and teacher's notes in the views, and (3) months when the view was mainly worked on. The total number of notes included in this quantitative analysis was 490. The notes collected within the rise-above notes, copied notes (i.e., notes created in one view and copied later on to support activities in another view) were not included in the analysis. Also notes related to studies of habitats of different animals, housing in different historical phases and geographical areas (i.e., integration of other subjects) were excluded from the analysis.

For the second phase of the analysis, we selected only the notes produced by the student teams (f=435), in order to examine more closely the contents of the notes. Although the actual analysis involved segmenting the notes to smaller, meaningful idea units, we report results at the level of notes in the present article. The analysis was performed with some standard procedures of qualitative content analysis (Chi, 1997) with the help of ATLAS/ti software. We employed a theory and data-driven approach for categorizing the content of the notes. In other words, the classification schema was created on the basis of a) preliminary analysis of the KF database and b) reflection on the data in relation to the theoretical framework of our study. This assisted in identifying the relevant aspects of the phenomena in question (Seale, 2006). The analysis produced the following five main categories: 1) design context, 2) design constraints, 3) design ideas and visualizations (the number of pictures, sketches, photos, models were counted manually), 4) calculations related to buildings, and 5) reflection on the project.

In the following sections, the design and implementation of the Architecture Project will be introduced. First, we will report the overview of the project. Second, relying on the Learning by Collaborative Design –model, we will describe 1) the design challenges related to architectural design context, 2) the creation of design ideas for the apartments, and 3) visualization and construction of design ideas.

Results

Overview of the architecture project

The total number of KF views created during the Architecture Project was nine. The teacher created two shared views, the Welcome view and the *Environmental Model* view, used by all the teams. Each team (N=7) had their own view, named according to their special design challenge or themes. Correspondingly, the team views were named as *Eco House* (considering especially ecological aspects, for example, recycling), *Sound House* (special attention to acoustics), *Water and Wind House, Green House, Community House, Small Apartment House* (consisting of only two apartments), and *Accessibility House* (for disabled people). Table 1 presents the number of student teams' notes and the teacher's notes in each view and in total. Further, Table 1 presents the months when the view was mainly worked on

	Name of the view	Month worked on a view	Student teams' notes	Teacher's notes	TOTAL
Shared views	Welcome	January	26	11	37
	Environmental model	February – March	185	32	217
Team views	Eco House	March – May	32	2	34
	Sound House	March – May	29	1	30
	Water and Wind House	March – May	30	1	31
	Green House	March – May	25	0	25
	Community House	March – May	57	3	60
	Small Apartment House	March – May	25	1	26
	Accessibility House	March – May	26	4	30
TOTAL			435	55	490

Table 1. The quantitative contributions of the Architecture Project's KF database

Table 1 shows how the KF database was gradually built during the Architectural project. The number of notes in the team views varied from 25 notes to 32, except for the *Community House* view, where the number of notes was 57. The *Welcome view* (f= 37) and the *Environmental Model* view (f=217) were constructed collaboratively by the whole class. The teacher's notes were mainly organizational instructions, task instructions provided by the designer, collective notes from the classroom discussions and summaries of what they have achieved thus far. The number of notes contributed per participant was approximately 22, however, this number does not take into account that almost all of the students' notes were written in teams or in pairs. Half of the notes were linked to other notes, indicating that the students built-on each other's notes, especially on the team views.

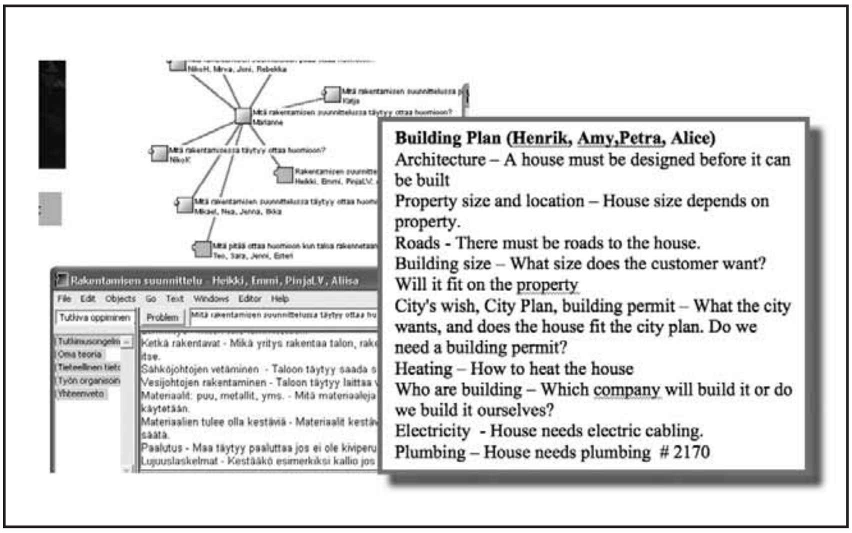

Figure 5. Part of the student team's KF note on issues related to architectural designing

The qualitative content analysis of the student teams' notes (f= 435) revealed (see Figure 4), that the main content of the student teams' notes was, as expected, related to design ideas and visualizations (f=141; 32%). The analysis of the design context 18% (f=78) and the design constraints 6% (f=28) acconted for approximately 25% of the contents of the notes. Also the calculations related to building volume played a important role in the design process (f=50; 12%). Moreover, the students reflected on their design processes (f=138; 32%), considering also aspects that were easy or difficult for them while designing. In the following, we will describe the main contents in detail, with examples from the project's database.

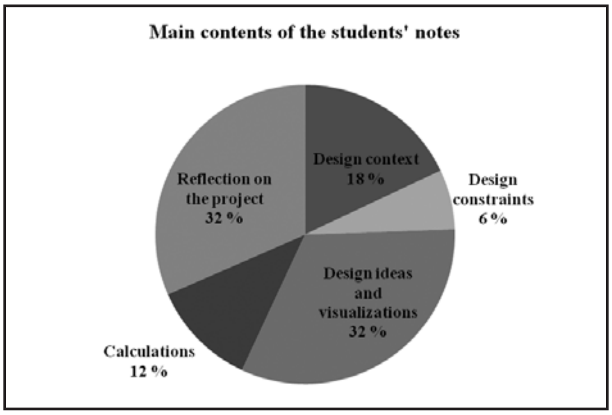

Figure 4. Main content of the segmented notes

Creating context and anchoring students' experiences for Architectural design process

The starting point for the Architecture Project was an authentic problem: to design apartment buildings for various user groups at a building site planned by the City of Helsinki. The architectural design process started, in accordance with the LCD model, with all participants performing a joint analysis of the design context. Before starting their actual architectural designing, the students were given orientation material about city planning, and they reflected on how to investigate and study the building or construction processes. The student teams reflected on what issues need to be taken into consideration in the construction design: soil, map, the size and location of the building site, pile work, traffic, water plumbing and electric wiring, strength calculation, and budget. Figure 5 represents part of one team's note of the issues by listing their considerations related to architectural designing.

This phase of students' design inquiry was facilitated by requesting students to analyze the design of apartment buildings in their own neighbourhood. Thus, the students were engaged in particular design-oriented knowledge practices in their areas of residence so as to anchor their personal architectural experiences. Students were asked to select a well or badly designed apartment building or duplex from their neighborhood, justify their selection (why the house was interesting to them), and make their assessment concerning its design characteristics. Working towards that end, all students drew pictures of the building as well as constructed written explanations justifying their design evaluations (see Figure 6).

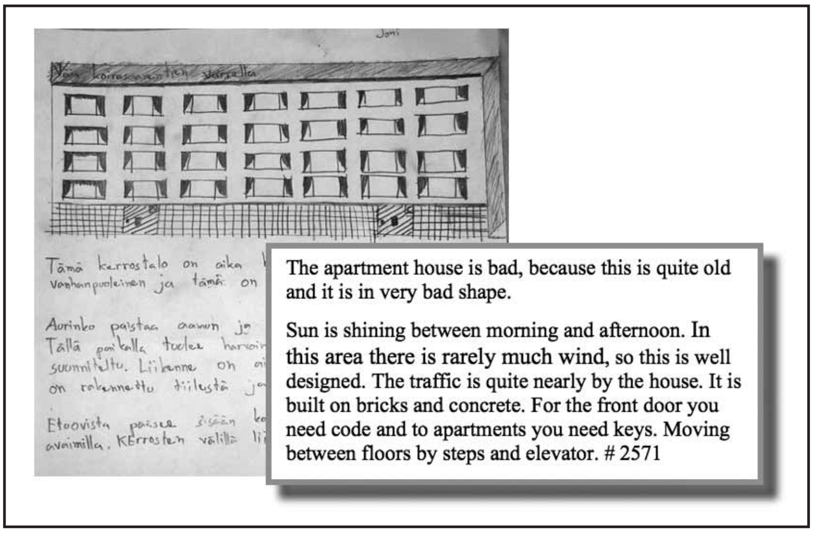

Figure 6. John's drawing of the badly designed house and justification for selection

From complex design challenges to explicated design constraints

The actual planned building site was located at Viikki, Helsinki, Finland (see the Welcome view). The students were given an aerial map of the area as well as basic information regarding city planning, such as the area's building plan, permitted building volume, and gross-floor area. Later during the spring, the students visited the area, and familiarized themselves with the actual building site under the guidance of the designer.

The design process was started by creating a shared concrete environmental model of the building site according to the area's building plan (1:500). The related KF view worked as a shared space for each team's planning sessions. The building site was divided into seven parts corresponding to the design teams. Each team was asked to design its own particular apartment building. In the *Environmental Model* view, students first started to conduct calculations regarding the permitted building volume and the gross floor volume. They also set up their first design goals. Subsequently, the student teams familiarized themselves with their own building site and regulations regarding their permitted building volume. Central concepts, such as massing (i.e., creating a balanced composition of each building scale and location), maximum permitted building volume, and the height of eaves (i.e., height of roofs) became familiar. The constructed environmental model and scale models, as well as the calculations of gross floor volume, and scale drawings were inserted to KF's views as pictures and texts. Figure 7 shows the *Environmental Model* view, where each team's specific building site and the buildings surrounding the area can be seen. The building sites were different in size and shape.

During massing and composition the students needed to consider, together with their team members, various constraints and specific characteristics of the building site: traffic, effects of sun, accessibility, and so on. All of these issues were authentic, important constraints related to the real-life architectural design context and requirements for permitted buildings. When reflecting upon on the effects of sun, wind, traffic, sounds, and accessibility, students decided that each team would adopt one of these as a special design challenge or theme. Further, the student teams were asked to self-organize their activities and create their own team views for their design ideas.

During the design process, the participants collected selected information and all emerging materials (drawings, texts, and photographs) to their own views. The student teams reflected upon, analysed, and elaborated the purposes of their houses, producing several design challenges. For example, the *Water and Wind House* team wrote down the following aims:

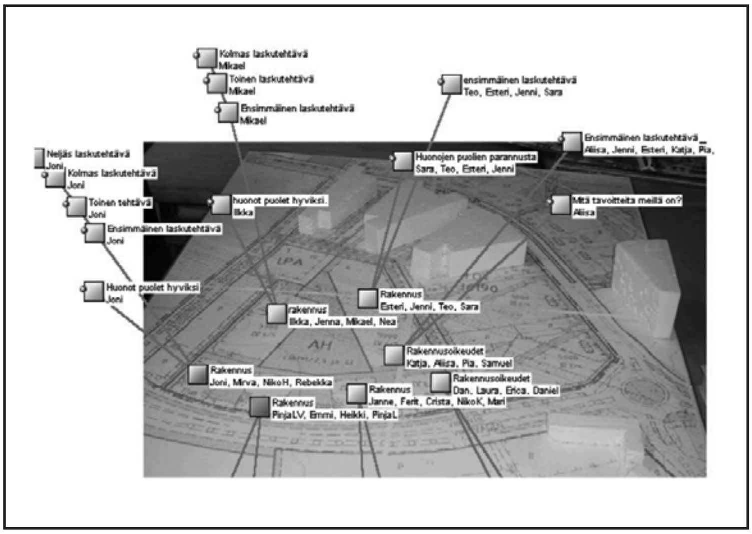

Figure 7. The Environmental Model view and students' notes in KF

We wanted to improve the basement so they would be more protected. The basements (storage units) can't be like that you can push your hand through the wall and see other people's basements because then it would be easy to steal others' belongings. If the house has a road nearby it would be prudent to include good soundproofing into the house so all the noise during the night doesn't seep in. The door to the house could be put facing away from the road and all the noise can not be allowed to reach all the way upstairs. If the house has a clubroom everyone should be able to use it and it should be on everyone's responsibility.(KF note number 2297)

The teams were working with various aspects of the design in parallel. The completion of certain design stages was, however, a condition for moving to the subsequent ones.

Designing and redesigning: Mediated sketches and constructing scale models

The cyclical and spiral nature of the architectural design process was actualized when the students were producing their shared design ideas concerning the buildings and while they evaluated and negotiated their design ideas together with the designer. The following is an example of the ideas produced by the Accessibility House team:

In a house made for people with disabilities, people could have a shared taxi which would take them from one place to another. Elevators would have seats so the occupants wouldn't have to stand in the elevator. As soon as you enter through the door, the lights would automatically turn on, and the elevator door opens automatically, and the moving sidewalk would turn on and lead the residents towards the elevator. This is done because if the house is occupied with people with dementia they may not remember to turn on the lights. The house would have a lot of nurses who go to the store and take care of the occupants for the residents. Escalators on every floor so if the elevator is full one can use that. For impaired children you could build a separate playground in the front yard. KF note number 2625

The functionality and size of the apartments were designed according to the users' needs. In the case of small apartments, common spaces were regarded as having a very essential role. For the apartment of a musician family, the Sound House team considered it necessary to have a large living room for a small home orchestra. Rooms of the green house needed to have enough space for plants. The nursing staff of Accessibility House needed their own apartments.

The design ideas were visualised by producing many kinds of sketches, from rough drafts to detailed floor plans. The sketches were produced with paper and pencils, scanned, and uploaded to the database. The participants also constructed prototypes constructed of available materials (such as cardboard); photographs of the prototypes (i.e., scale models) were scanned and inserted to the database. Efforts in learning through collaborative design thereby, took place through developing conceptual design ideas, embodying and explicating the ideas by constructing external representations, and giving the ideas a material form as various kinds of scale drawings and models. During construction designing, the participants created several sketches and drawings of floor plans and facades (Figure 8). The purpose of these sketching activities was to understand the difference between a sketch and the final drawing.

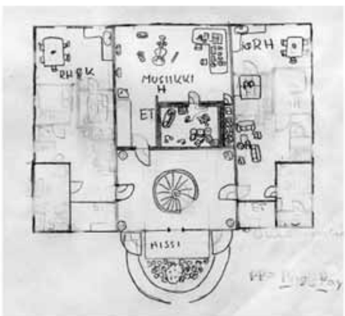	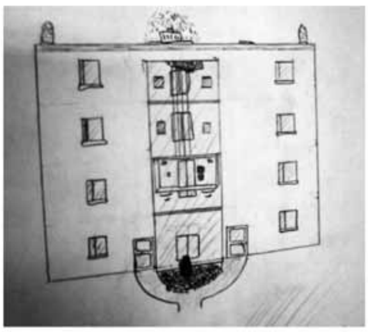	
Floor plan of the Sound House (1st floor)	Facade sketch of Sound House	Final facade of Sound House

Figure 8. Various sketches regarding Sound House

In pursuit of the Architecture Project, it was essential to master calculations of floor plans and various measures regarding buildings. Moreover, while working with calculations needed for construction, students were constantly transforming numbers from one scale to another. A 20:1 scale was most commonly used; this scale was also used while the students were creating scale models of the apartments of their buildings.
The students were guided to construct a cardboard figure of themselves, in order to investigate how humans use space. These cardboard figures assisted the students in assessing the size and shape of living spaces in relation to themselves. Students were asked to think of the measures from the perspective of a person using the building, moving from one room or area to another, and living within an apartment. Spaces needed for movements, external doors, stairs, and elevators had to be taken into consideration before starting to work with the floor plans. With the help of the cardboard figure, it was easy to explore how one can move and dwell in different parts of the house and how much space was needed for this or that part of a room. The cardboard figures were concretely located in the apartments while the participants were working with their interior designs. While measuring, the students also used information about their own dimensions. These kinds of architectural knowledge practices (calculating areas, transforming different scales in different drawings, drawing floor plans and façades) were very challenging activities, as stated by one student in her reflection:

The hardest part of this project was probably the calculations, drawing according to scale and because everyone in our group did their own floor's blueprint. It was very hard because we had to constantly measure to make sure everyone had the same scale. We began our work with the facade. When we had finished the facade, we realized that the window location did not fit inside the rooms. Some of the windows went straight through the walls. We had to erase the windows and copy them again in the right places. Then we thought, while making the miniature model, that the room location was odd. The bathroom was the biggest room in the house; in the bedroom one could barely fit a bed. So we decided to change the order of the rooms. We also had to change the placement of the windows. By the sixth layout the bathroom and bedroom filled one side of the house.

Conclusions

To provide students with an authentic experience of architectural designing, we created a learning environment that simulated architectural practices (see also Hansen, 2010). Consequently, students were guided to develop shared design ideas and solutions, create and build-up scaled drawings and models, as well as jointly plan advancement of their process. This involved the guiding and coaching activities of the design expert: The designer familiarised the students with planning regulations, requirements of the building site, and different kinds of scale models that architects work with.

The previous sections highlighted the role of conceptual, visual, and material artifacts in the technology-mediated learning process and described how the design practices were actualized during the Architectural project. The previous sections also described what kind of learning process emerged during the project. The Architecture project put emphasis on how to engage students in creating both new conceptual and material artefacts in collaboration with one another. Thus the project included the use of KF software and hands-on drawing and modelling activities to support students' mathematical and design inquiries. The results depicted some examples of the students' conceptual and visual ideas related to designing houses for specific purposes. The quantitative analysis of the KF views and notes revealed some of the characteristics of the technology supported collaborative learning process. However, to investigate how the ideas of the LCD model characterized the students' design process, a qualitative content analysis was conducted for the segmented notes. The analysis of the design context revealed that students were able to take various aspects into consideration while designing a house, i.e., the size and location of the building site, pile work, and need for strength calculations. While defining the constraints, they considered aspects related to safety, privacy and functionality of the rooms etc. As expected, the students produced many design ideas and corresponding visualisations. The present project involving design activities includes the notion that design is an iterative process that requires the creation, evaluation, and redesign of architectural solutions. Thus, the designed representations and models were resources for thinking and developing architectural ideas further. At the end of the project, the students arranged, together with the teacher and designer, an exhibition of the Architecture project and made posters presenting their main design constraints, design ideas and the scaled models. To conclude, all these were essential elements of Learning by Collaborative Designing that apparently supported students' design process and design learning.

The overall project was supported by the technology-enhanced learning environment. A central aspect of the present project was to explore possibilities of collaborative designing with special focus on the participants' parallel pursuit of material and conceptual artefacts. Beyond conceptual artifacts, the participants were working with materially embodied drawings and physical models. The participants engaged in learning by collaborative designing in terms of carrying out various concrete and material as well as epistemic and conceptual activities, such as taking measurements, doing calculations, reading and writing, sketching and drawing, and prototyping and testing scale models. Material activities taking place in a socio-cultural environment and technology-mediated activities reciprocally supported one another. KF's shared space allowed the participants to represent ideas and visualisations as well as material models created by them. The KF provided support for such heterogeneous design practices: It was essential to be able to scan the students' drawings and upload the drawings together with digital photos to the KF's database.

Discussion

The purpose of the Architecture project was to examine how practices of collaborative designing with the help of a technology-enhanced learning environment may be implemented in an upper elementary classroom. Toward that end, elementary-school students were engaged in architectural knowledge practices. Engagement in such activities involved working with ill-defined problems; these arise in an authentic design context; often ones never before encountered. A limitation of the present study was reliance only on data produced by participants to KF's database; the actual classroom practices were not videotaped due to practical reasons. Students worked in teams and went through many of practices involved in actual architectural design. In accordance with the pedagogy of the Learning by Collaborative Designing, they took part in field studies at the construction site, analyzed houses and apartments in their environments, as well as designed houses for specific purposes in their teams. We can conclude that Learning by Collaborative Designing pedagogy provided novel possibilities for developing the processes of learning in design and technology education. Students from the elementary level can be guided to engage in design-based collaborative inquiries in computer-supported contexts.

Many researchers (e.g., Carroll et al. 2010; Hansen 2009) emphasize that the most relevant aim in D&T education is that the students will be able to describe and represent different solutions for the design of a product and to consider the design specification of form and function by using sketches or other material representations. The main intention in D& T education is that the students learn the whole design process from the first idea to the finished product. Engaging in the whole process of designing sheds light on how professional designers and architects work on their professional projects. A challenge for the D&T education is to support the use of various visual representations because students prefer to manipulate concrete material instead of visual representations (Rowell 2002; Welch et al, 2000). While technology-enhanced learning environments provide tools for creating, sharing, discussing, and advancing textual documents, a special challenge in the future is also to use CAD/CAM technologies that allow visualization, modelling, and manipulation of collaboratively designed artefacts (Gershenfeld, 2005; Hodgson 2006). Students' access to the relatively new technologies connected with computer aided design (CAD) and computer aided manufacture (CAM) will provide schools with new possibilities to simulate the concept of concurrent professional designing (Hodgson, 2006). The CAD and CAM technologies based on the idea that computer based 2D designs are translated into physical artefacts using, for example, a three-axis engraver/cutter to machine the parts. With new CAD/CAM technologies students develop knowledge and skills to model, design and construct ideas into physical artefacts as an interactive process (Hodgson 2006).

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