
Pirita Seitamaa-Hakkarainen¹, Anna-Mari Raunio², Asta Raami³, Hanni Muukkonen⁴, & Kai Hakkarainen⁴

¹Savonlinna Department of Teacher Education
²Department of Home Economics and Craft Science, University of Helsinki
³UIAH Media Lab, University of Art and Design, Helsinki, Finland
⁴Department of Psychology, University of Helsinki, Finland

Correspondence concerning this paper should be sent to
Professor Pirita Seitamaa-Hakkarainen
Savonlinna Department of Teacher Education
University of Joensuu
Kuninkaankartanonkatu 5
P.O. Box 55
FIN-57101 Savonlinna
Finland
Tel: +358-15-5759641
Fax: +358-15-531060
E-mail: pirita.seitamaa-hakkarainen@joensuu.fi
ABSTRACT

The purpose of the present study was to examine how collaborative designing could be facilitated by a new generation networked learning environment (Future Learning Environment, FLE-Tools) and to analyze whether and how students working in the environment were able to share their design process. The study was carried out by analyzing qualitatively knowledge posted to FLE-Tools’ database by three courses of first-year textile students (N=34) who were engaged in a collaborative design project that focused on designing clothing for prematurely born babies. The study indicated that designing in the network environment facilitated engagement of expert-like designing in a sense of supporting specification of constraints related to designing clothing to premature neonates through in-depth problem structuring and search of new information. A design challenge of FLE-Tools is to provide more effective tools for collaborative work with visual sketches as well as developing tools and practices that would help to share knowledge emerging not only in the conceptual but also during the actual manufacturing phase of designing.

Keywords: design spaces, collaborative designing, knowledge-building environments, shared knowledge
Introduction

The purpose of the present exploratory study was to analyze how university students’ collaborative design process may be supported by a networked learning environment. Although designing has been intensively studied by cognitive researchers (e.g., Akin 1986; Goel & Pirolli 1992; Goel 1995; Seitamaa-Hakkarainen 1997; Seitamaa-Hakkarainen & Hakkarainen in press a; in press b), only a very few studies, however, have specifically analyzed design processes with respect to collaboration or teamwork (Akin & Lin 1995; Hennessy & Murphy, 1999; Perry & Sanderson 1998; Valkenberg & Dorst 1998). Nevertheless, collaboration is an essential aspect of professionals’ practical activity in the field of modern design (see, for example, Ferguson 1992; Nonaka & Taceuchi 1996).

The present study is based on an assumption that the new collaborative technology may significantly facilitate collaborative designing. A fundamental aspect of the design of computer supported collaborative learning (CSCL) environments is to provide users tools for posting knowledge productions into a shared working space and providing tools for progressive discourse interaction between the users (Scardamalia & Bereiter 1993; 1994). Through these kinds of collaborative learning tools, the users are able to rely on the socially distributed resources of the learning community in conducting their study projects (e.g., Salomon 1993; Pea 1994). A central principle of designing collaborative technology is to provide structures and activities that foster monitoring of one’s own and the other students’ comprehension and reflect advancement of inquiry (Bereiter & Scardamalia 1993; Brown & Campione 1996).
The technical infrastructure of the present study was provided by a networked learning environment, called the Future Learning Environment (FLE-Tools) developed by the Media Laboratory, University of Art and Design, Helsinki, and the Department of Psychology, University of Helsinki (see Leinonen, Mielonen, Seitamaa-Hakkarainen, Muukkonen, & Hakkarainen 1999; Muukkonen, Hakkarainen, & Lakkala 1999). The FLE-Tools environment is designed to facilitate expert-like working with knowledge and collaborative design. Working with knowledge, which we call ‘knowledge building’ (Scardamalia & Bereiter 1994) involves intentionally treating elements of inquiry — e.g., problems, design ideas, tentative solutions — as objects of knowledge and using them in the construction of extended bodies of discourse reflecting deep, expert-like understanding. FLE-Tools engages students in generating new design ideas and collaboratively working to further develop their ideas. The system provides tools for discussing ongoing design processes as well as sharing of conceptual and visual design ideas. The users are able to access it from any internet-linked computer and post ideas and thoughts to FLE-Tools database directly or using their standard office applications and productivity tools. The ‘knowledge’ posted may be in various formats, such as text, graphics or video.

In this paper, the role of collaborative technology in supporting expert-like designing is examined by reporting results from a pilot experiment of using FLE-Tools in a university-level design course. The study examines university students’ collaborative design process as it occurred in a complex and authentic design task--designing clothing for premature babies--and explores how students worked in the learning environment to jointly advance their design knowledge, determining and applying design constraints to premature babies’ clothing.
Generic Characteristics of the Design Process and Design Practices

In order to provide computer support for expert-like designing, one has to consider generic characteristics of design process and develop tools and practices that would foster participation in these kinds of processes. Designing may be understood as a form of complex problem solving (Goel & Pirolli 1992; Goel 1995). Accordingly, designing can be defined as a cognitive process intended to produce a solution to a design task. Goel and Pirolli (1992; see also Goel 1995) conceptualized design-problem space by using several invariants, which they argued collectively constitute and structure a design-problem space, and are common to all typical design tasks. The actual process of designing is more complex than assumed by the traditional cognitive approach because it involves various cultural-historical, contextual, and situational processes. Nonetheless, the problem-solving approach appears to provide a sufficient basis for the present study, one that focused on investigating as they were guided to solve design problems.

The most important invariant has been labeled design constraints. Design constraints form the design context by defining, for example, the intended users and their special needs for the artifact and function of the artifact. Further, designing may be conceptualized as a process of searching through two problem spaces, i.e., composition space (visual designing) and construction space (technical designing) (Seitamaa-Hakkarainen 1997; 1999; in press). The visual and technical elements involved in designing must be considered and related to each other, within the constraints in order to create a functional and aesthetic solution. The designer works simultaneously between composition and construction spaces controlled by
the characteristics of the design constraints and design context (Seitamaa-Hakkarainen 1999, in press). Figure 1 presents an abstract description of the relations between basic constituents of design process.

Designing is an iterative process by nature; i.e., design solutions emerge gradually as a process of structuring and restructuring, composing and decomposing the problem, defining and redefining constraints of designing, and generating and testing design solutions (Akin 1986; Goel 1995). The designer must generate and represent a great deal of additional information during the problem solving, in order to find plausible solutions. Cognitive research on expertise indicated that novices tend to generate problem solutions without engaging in an extensive problem structuring whereas experts focus on structuring and restructuring problem space before proposing solutions (Chi, Glaser, & Ress 1982; Glaser & Chi 1988). An indication of expert-like designing would, therefore, be engagement in an intensive problem structuring through examining and determining design constraints.

Cognitive research on design process has, traditionally, examined designing as an individual mental process. However, current cognitive theories are more and more emphasizing socially distributed nature of cognition (Hutchins, 1995; Norman, 1993) and the role of social collaboration in modern designing (e.g., Ferguson 1992). An essential aspect of professional design process is to share knowledge, such as design ideas, visual sketches, and interpretations, among members of a design team. Moreover, designers frequently search for and use information from other experts or other related disciplines to help them to construct
new knowledge of constraints related to the design topic. In the present study, collaborative designing is understood as a process of actively communicating and working together in order to share a design task, jointly determine design constraints, and coordinate efforts to create a shared design product (see Dillenbourg, Baker, Blaye, & O'Malley, 1996; Hennessy & Murphy, 1999). Engeström (1992) argued that the nature of collaboration is dependent on whether the actors are sharing the same design object or not. In his framework for describing types of collaboration, **coordination** means that actors are carrying out individual design tasks without having a shared object whereas **cooperation** refers to collaborative process in which the actors focus on a shared problem and try to negotiate a mutually acceptable way of solving it. A characteristic of **communication** -- the highest form of collaboration -- is that the actors are not only sharing a design object but also conceptualizing their mutual interactive relationships through transformative communication. Social collaboration appear to has a particularly important role during the conceptual phase of designing, i.e., while generating and articulating design through searching new information that would help to determine design constraints and produce a satisfactory design.

**Technology Support for Collaborative Designing**

New technology-based learning environments have emerged through cognitive research that provide the users tools to for collaboratively building and sharing of knowledge and solving problems together (Scardamalia & Bereiter 1994). The present study relies on the Future Learning (FLE-Tools) that is a networked learning environment providing a distributed database designed to support collaborative designing. The Future Learning
Environment (FLE) is based on a three-tier architecture in which the FLE-Tools software is distributed among three servers: The database server, where most of the changing information (the database and search engine) resides, the application server that handles most of the logic in conjunction with the database server, and the www server that handles the backend www-processing and glues the other servers together. The users are able to access the FLE-Tools environment from any internet-linked computer (TCP/IP with any HTML 3.2 compliant browser such as Netscape Navigator 3 or later) and they are able to work with FLE-Tools database using their standard office applications, producing documents in various formats, such as text, graphics, video or WWW-links. Some non-critical features can only be accessed by browsers with a JavaScript implementation. The Internet accessibility allows small groups working at different locations to coordinate their activities with the tools provided by FLE.

One of the specific aspects in FLE research and development project is to create supporting tools for collaborative designing, so that multiple actors can simultaneously work and communicate through visual representations in the virtual design environment. The FLE-Tools environment consists of several modules that facilitate collaborative knowledge building and aid the design process, and it provides ‘thinking tools’ for organizing and structuring of these processes. The main modules of the FLE-Tools that will be described include the Virtual WebTop, the Knowledge Building Module, the Jam Session Module and the Library.
Virtual WebTop

The Virtual WebTop refers to a personal adjustable display window, which is automatically opened as the user logs onto the system. The Virtual WebTop contains graphical links, represented by folders, that give information about the course attended, links to the Virtual WebTops of the other participants of the group. The Virtual WebTop is a place for the user to store his or her documents created by standard office applications in various formats. It is the main center for the user’s own knowledge production, and may contain large documents such as research proposals, term papers, designs, or project reports that are related to one or more FLE projects. The Virtual WebTop also has a search engine built in, enabling search into materials previously produced in other courses and also all materials in the Library. In the background of the Virtual WebTop is a metaphor of an open office in which you could go to work in any desk, observe what other people are working on, and leave your own notes. Accordingly, the Virtual WebTop allows a student to visit in WebTops of other users in the same course. Through examining fellow students’ Virtual WebTops, students are able to share their achievements and to get acquainted to their fellow students’ interests, and to observe their studies across different courses. Coordination of collaborative design efforts is supported by a tool that allows a student or tutor to leave messages to other participants Virtual WebTop as well as review messages received and sent.

The Knowledge Building Module

The Knowledge Building (KB) Module provides a shared space for working together
for solving problems and developing ideas and thoughts generated by the users. The Knowledge-Building Module is a shared space for constructing coherent, larger portions or bodies of discourse; in the present case, specifically for discussing topics, design ideas, and tentative solutions generated by the user. All KB messages within a course are posted to the shared space, visible as lists of messages. Each KB discussion is accessible only to the users enlisted as participants of that specific course. In the conceptual phase of designing (i.e., preparation and problem-structuring phase preceding actual production), it supports generation, externalization, and explication the design ideas and determination of the design constraints. A student preparing a note for posting is asked, pursuant to the goal of knowledge building, to label his or her note by choosing a Design-Thinking-Tool label (i.e., design problem, working idea, comment, deepening knowledge, summary, metacomment, and help) corresponding essential aspects of design process (see Figure 2).

Figure 2 schematically depicts various aspects of collaborative designing within the FLE environment. The purpose of the model is more to illustrate important aspects of computer-supported collaborative designing than to provide a fixed or inflexible design framework. Through structuring of students' postings to FLE's database by using the Design-Thinking-Tool label, the system is constructed to provide cognitive scaffolding that encourages students to engage in expert-like designing. By categorizing his or her design notes posted to KB-module, the user is guided to specify his or her design idea, generate and articulate multiple working ideas and evaluate those critically, search for new information, comment on the fellow users design process and share the whole process with the other
The Jam Session module

FLE contains Jam Session module that is designed to facilitate collaborative designing through providing a space for collaborative construction of digital artifacts. The module creates a graphic representation of development of a knowledge object and, thereby, assists in making thinking visible (Brown, Collins, & Duquid 1989; Scardamalia & Bereiter 1989). It helps the students in the dynamic development of a design project by providing graphic representation of different versions of the design sketches they are working on (i.e., portfolio). Students may import their own digital artifacts (e.g., pictures, videos, text and software) to the session and let other users further elaborate their ideas and comment on the work in progress. Moreover, the other students can continue and develop the imported design sketch, on the condition that all students use the same graphics software (e.g., Photoshop). In its simplest use, all visual documents are stored in Jam Session and it provides means for recording and storing all the changes to the documents (i.e., different versions). Figure 3 presents the window of the Jam Session Module where one can see a graphic representation of the stored visual representations and their progress. In the figure are presented some models of clothes designed for prematurely born babies by students who participated in the present study -- as explained in the following sections.
The Library

Finally, the Library allows the users to share the documents produced in various formats: text, graphics, audio, video, multimedia, or www links. The Library contains course materials chosen by the tutor as well as materials produced by the users. Materials from earlier courses may also be stored in the Library and made accessible to later users. The environment is intended to provide tools for helping teachers and students to create digitized study materials, to collect interesting link addresses to folders, and also gain access to other libraries linked to the internet.

The present study focuses on analyzing how first-year university students working in small teams to design clothing for premature babies shared their knowledge and expertise and searched collaboratively for new knowledge from different sources of information while working in the FLE environment. The problem addressed in the study was to analyze whether and how working in the network environment supports participation in collaborative design process. Particularly, the study aimed at examining how basic elements of designing, such as composition, construction, and constraints designing, were represented in the students' design process. Further, we analyzed how the participants processed authentic expert knowledge and other design teams’ experiences, in order to deepen their understanding of the design constraints related to these premature neonates' clothing. The data represent our work-in-progress, being exploratory in nature and intended to provide support for further development of collaborative design tools for the FLE-Tools environment.
METHOD

Research Procedure

The data was collected from a 15-week design project on ‘Clothing-design Project for Prematurely Born Babies’, and students were using FLE-Tools environment during the entire design process. In the study participated 34 first-year, textile teacher-students at the University of Helsinki. The students were divided in three FLE-design courses, each consisting of approximately ten students. Further, the project was organized so that the students worked in three or four students’ design teams within each FLE-design course. Within each design course students were able to observe or participate in the other design team’s knowledge-building process but they were not able to follow activities in the other FLE-design courses.

The design task was a very challenging, real-life problem: the students were asked to design and produce functionally and aesthetically delightful clothes for prematurely born babies. The students were instructed to intensively collaborate within 3 to 4-person groups across the whole project. The clients of the project were the Association of Sick Children’s Hospitals in Finland, and the Department of Prematurely Born Babies, Helsinki University Hospital. During the project the students received some background information, such as 1) research articles concerning the prematurely born babies’ clothing and 2) practical information about functional requirements for the clothing being designed, from nurses working with prematurely born babies. In addition, the students had an opportunity to visit
the Department of Prematurely Born Babies. Experts on premature babies participated in the project by providing introductory lectures. Moreover, the designs produced by the students were actually tested in an authentic hospital environment, in order to provide feedback about functional aspects of the prototypes being designed. In the end of the projects, 200 pieces of clothes were produced. In addition, the students were informed that productions of each whole group rather than of the contributions of individual students were going to be assessed. They were further informed that their individual and collective contributions to FLE’s database formed an important aspect of assessment.

The entire design project consisted of four basic stages: 1) knowledge building and visual designing, 2) prototype making, 3) testing of the prototype (in a hospital), and 4) production of the clothing. During the first four weeks, the students worked independently, building knowledge of neonates, especially those prematurely born through elaborating their design ideas, sharing new knowledge among their team members, and specifying their design problems. In visual design sessions, they produced visual sketches, which were scanned to the database. Each member of the design team designed one individual prototype that was tested and evaluated in the Department of Prematurely Born Babies. After prototype testing, each team jointly decided which one of the prototypes they would further develop and produce through considering rational and effective mass-production methods. In this study, we are limiting our analysis to the database, which was produced during the knowledge building and visual design stage (10 weeks), because the FLE-Tools environment was not intensively used in making actual prototypes and pieces of clothing by sewing.
The study was based on an analysis of the students' written productions posted to FLE's database. In addition, we analyzed students' sketches, portfolios, and prototypes. We also interviewed the teacher. The following analysis of results, however, was mainly based on a qualitative analysis of the students' design discourse as recorded in the learning environment's database.

Methods of Data Analysis

The knowledge posted by the students to FLE’s database was analyzed by methods of qualitative content analysis in order to examine the nature of their design process. The knowledge-building messages posted to the database were segmented into propositions representing one main idea (Chi 1997). The inter-coder reliability of segmentation was .91 indicating that the reliability of segmentation was satisfactory. Each segment representing the main meaning was coded and analyzed using qualitative content analysis.

The students productions posted to FLE-Tools’ database were classified according to several variables that represented essential aspects of collaborative designing by using ATLAS.ti program (Chi, 1997; see Seitamaa-Hakkarainen 1997 for a more detailed description of the method). The classification schemata consisted of the following categories: design thinking, design activity, and design content, type of the note, and type of reference. On average, the reliability coefficient of classifying the data across these five variables was .88. A summary of the classification schemata applied in the study is presented in the Figure 4.
The design-thinking category consists of specifying design context, working idea, comment, new information, and metacomment. These categories represented the scaffolds that were used to facilitate collaborative designing. However, the students used these scaffolds to categorize their notes as a whole whereas the present investigators applied the scaffolds to categorize the segmented ideas produced by the students. By specifying design context the design problem was determined (Example: Does anyone know how big are prematurely born babies?). Design progresses by articulating and elaborating of different working ideas through which the final design emerges (I have been sketching a body-type of clothes for 40 cm babies). During the design process students can comment on each other's design ideas and design information. They also searched and provided new information concerning design context or design elements (I found some nice pictures from www.premierstore.com, Go to look). Through metacomments these students assessed whether the design process progressed in the desired direction, appropriate methods were used, how the design task was shared, and accomplishments of members of a design team (Hi, we have to now discuss what kind of clothes we are going design. Please make your comment as soon as possible so that we can go on).

In order to examine how the students processed design constraints and what was the role of the visual and technical design spaces in their designing, it was used a variable labeled as design content. The variable refers to the actual design content: 1) design constraints (e.g., babies, parents, hospital environment/treatments), 2) composition design (size, pattern,
colors), 3) construction design (material, technical solutions for sewing etc.) or 4) the type of clothing (i.e., shirt, pants etc). Further, we used design-activity category to assess the students’ participation in the different phases of design problem solving that are generally present in design process. The variable consists of 1) problem structuring, 2) problem solving, and 3) decision phases. These categories were easily identified in the design statements. We were particularly interested in whether the students would engage in intensive problem structuring and careful consideration of design constraints rather than producing immediate solutions, such as novices are frequently doing.

Further, we assessed the cognitive value of interaction between the students by analyzing each segment according to whether students provided or requested information from the other team members or generally commented the design process (type of comment). Type of knowledge processed by the students was assessed by using a variable labeled as type-of-reference (see Hakkarainen 1998). This variable represented statements in which the students were explicitly referring to the source of information used in designing. The variable consists of the following subcategories; explicit reference 1) to literature (including the Internet) 2) to the experts, 3) to other team members or other FLE-students in the same course 4) to the friends or relatives; or it contained reference to 5) the student's own inference.
Results

Contents of the Participants’ Design Thinking

An examination of FLE-Tools’s database indicated that overall the students engaged in rather intensive work in the learning environment. According to the estimation of the teacher, students appeared to be very motivated in working with FLE-Tools. In order to analyze collaboration in the design process, we conducted detailed analyses for three different design teams. We selected randomly one of design team from each of the three FLE design courses. Team A (three members) produced 28 knowledge-building notes, Team B (three members) provided 52 notes, and Team C (four members) produced 51 notes. Although there were considerable between-student differences in participation in FLE work (some students became extremely active while a few students participated hardly at all), overall these groups appeared to represent a significant degree of participation. The entire database of these three design teams consisted of 454 design statements.

The students were guided to engage in expert-like designing by using a series of scaffolds. An examination of the students’ productions indicated, however, that their notes frequently consisted of statement that represented different categories of design thinking (i.e., working ideas as well as new information). Consequently, we analyzed the nature of the students’ design thinking by examining what category of design thinking each of the segmented design statement represented. The analysis indicated that as much as 32% ($f=143$) of the statements produced by the three design teams represented new information; 30%
(f=134) of statements represented working ideas; and 14% (f=65) of the statements defined the design context. Moreover, the metacomments concerning the project or organization of design tasks were as much as 18% (f=81), and comments as little as 7% (f=31) of the statements produced by the teams.

Further, in order to obtain a comprehensive information about their design process the students’ design thinking was analyzed in relation to different phases of their design activity. The analyzed database revealed also that the design teams were mainly structuring the design context and design elements since 58% (f=263) of the statements posted to the database represented problem-structuring activity; 30% (f=138) represented problem solving; and only 8% (f=35) represented decision making.

A detailed examination of the students’ design activity indicated that during problem structuring the students dealt with new information in 51% (f=126) of the statements and they structured the design context in 21% (f=52) of the statements. In problem solving, 67% (f=92) of the statements represented, as one might expect, working ideas (i.e., possible design solutions). The statements presented in the decision-making phase represented mainly working ideas (i.e., decision of the design solutions). The role of new information during problem structuring indicates that the students really expanded their understanding of the constraints of designing clothing for premature neonates and shared their cognitive achievement through the database. It is encouraging that the inexperienced students who have a tendency to jump directly to solutions, engaged in a very intensive problem structuring activity.
An examination of knowledge posted by the students to FLE-Tools’ database revealed that the students' own inferences composed the main source of information (51%, \( f=235 \)). Simultaneously, however, they read the given materials and searched intensively for various information sources in order to understand all aspects of designing clothes for premature neonates. Approximately 18% (\( f=83 \)) of the design statements referred to expert information and 17% (\( f=77 \)) to other team or course members. References to literature, the Internet, and research articles consisted of 9% (\( f=41 \)) of statements. Further, there were also references (4%, \( f=18 \)) to information obtained from friends and relatives who had worked with the neonate babies or who had prematurely born babies.

The following excerpt represents a collaborative knowledge-building discussion between three members of team C. It indicates that these students tried to understand one special piece of clothing for the prematurely born neonate babies, which was mentioned in the nurses’ lecture and the manner in which they started to develop new working ideas based on that information.

*Are the clothes, which we are designing for only to be used in the hospital, or do the specifications/directions mean that those babies/parents will get those clothes to take with them when they go home. In other words are those clothes to be recycled to other kids in the hospital? (Carita)*

*I understood that these items of clothing will be made for the hospital and will stay there to be ‘recycled’. (Nina)*
This means that selected fabric have to endure continuous washing and hot water.

(Nina)

Do you understand that nurse's description of the ‘apron-type’ item of clothing which the smallest premature neonates are wearing? (Carita)

I understood that the apron-like dress will be put ‘front on' and the back seam is open totally, so this item of clothing is like a blanket with sleeves. (Brita)

What was the reason that it is just a blanket with sleeves? (Carita)

Is it easy to put on the baby or important because of the baby's skin? (Carita)

Could this ‘apron’ be like a sleeping bag with sleeves, which would, though, be open on the bottom edge? (Carita)

That would be nice and warm, if it will be made of double-sided tricot (knit).

Then most of the seams can be hidden so that they are not inside or outside of the cloth. (Carita)

Further, we conducted analysis to examine whether the learning environment would facilitate consideration of design constraints in the participants’ designing. The analysis revealed that design constraints played a significant role in the students' designing: 32% (f=146) of the design statements dealt with the design constraints. The construction design (i.e., technical design aspects of the clothes) were handled in 26% (f=116) of the design statements. Only 17% (f=78) of the statements were considerations of the visual aspects of
the clothes (i.e., color, fabric pattern etc.) whereas 18% (f=80) of the design statements considered different types of clothing (pants, dress etc.) suitable for the prematurely born babies. These findings indicate that the student used FLE-tools actively to construct and structure knowledge of design constraints related the premature neonates and special aspects related to their clothing.

I thought one more requirements to add... that the nurse I met emphasized all the time, that the edges of the sleeves have to be so loose that the adult's hand will fit there. The nurse has to pull the baby's hands out every time she is putting clothes on. (Cathy)

Of course tricot fabric will be elastic, but we have to avoid making them too tight!! Just let's try to remember this ... and so many other things too!! (Cathy)

The cognitive value of interaction was examined by assessing whether they engaged in progressive discourse interaction focused on advancing their design assignments and sharing of their cognitive achievement. The analysis indicated that the students provided information to their fellow designers in 63% (f=286) of statements and requested information from members of their design team in 20% (f= 92) of the statements. In 17% (f=76) of the produced statements students generally commented on the collaborative design process. The high number of information-providing statements suggests that students were motivated to share their knowledge within their design team while seeking more information and defining the design constraints in depth. During problem-structuring and problem-solving activities the design teams appeared equally to provide as well as request information and ideas.
However, during decision-making stage the participants made only very general-level decisions by commenting on the design process and the organization of each member's design task; the final detailed decisions were made only after getting feedback from the prototype testing.

The teacher reported that the FLE environment provided significant support during the information-search phase of designing. The environment helped her to provide information to the students; she was able to see how the students were progressing. The system further helped the students to see how they felt in the beginning of the course, and to reflect, at the end of the course, upon their initial assumptions and starting points; this would have been very difficult to achieve in any other way.

Different Patterns of Collaboration

The results above highlighted the various aspects of the collaborative design process and its content across all students working in the three groups. However, each design team was working in its own way, and each member appeared to have a different knowledge-building role and made a different contribution to the knowledge-building discourse. In the following we will briefly describe the nature of the teams’ design processes in order to get a comprehensive view about different practices of collaborating in the FLE-Tools environment and to assess contributions of each student on his or her team’s collaborative process of designing.

Team A was very productive in spite of the fact that the number of statements
produced by the students was relatively small. Each member of Team A (Rita, Mary, and Greta) participated about equally in the design process. Rita was the most active in that group and appeared to play a critical role in bringing new knowledge about design constraints to the other teams members (53% of her statements). She also participated in the discussion on the different cloth types and construction solutions. Mary provided ideas for construction problems and participated in making decision of the type of clothing to be produced. The main part of team A’s external (as distinguished from their own inferences) information came from experts (lectures and visit to hospital) rather than from friends or relatives. Greta appeared to follow other teams' design processes in that particular FLE -design course and imported new information from the other teams of the course. It was typical for Team A’s design process that they clearly decided together same basic aspects of the clothing they will design (e.g., material and size), and they produced various sketches and prototypes based on a shared solution. Intensive collaboration was a characteristic of this team's designing in the sense that their work focused on a shared design object jointly constructed during the process.

In Team B’s work, Theresa was the most active, providing 88 statements; Ann provided 50 statements; and Cathy produced 30 statements. Theresa's statements evenly represented all design contents, although she emphasized slightly more construction solutions (32%; \( f_1 = 28 \)) than other design contents. Cathy considered different aspects of design constraints in most of her statements. Ann was the most active in bringing in new knowledge about design constraint (58%, \( f_2 = 29 \)). The members of Team B acquired design knowledge from all the sources, mainly from experts and other course members, but also from literature and the Internet. Further, each member of the team had some connections with friends and
relatives who had experiences of neonate or premature babies and all of them actively provided acquired information to shared space. It was characteristic of Team B to negotiate about specific aspects of the item of clothing (size and type) being designed. The following transcripts illustrate how members of the teams approached a shared solution to their design task.

I was thinking that we could make some kind of zip-suit? What do you think? Let’s discuss this more during the next week. (Cathy)

I was also thinking some kind of zip-suit or some sort of "apron-like" system? Those would be suitable both for boys and girls. (Ann)

We have to remember that the zip-suit has to be very easy to put on, so that when you are changing diapers you would not need to take to whole zip-suit away. (Ann)

Do you, Cathy or Theresa, have any wishes about the size of baby we will design it for? (Ann)

A zip-suit also came to my mind, but I think that many others are having the same idea. Shall we try to come up with something more original? (Theresa)

I have an idea of culotte (divided skirt), but aren’t we supposed to make our own designs and then select one of those? (Theresa)
Would some kind of hat or bootie system be completely out of consideration? Is it sufficiently "cloth-like"? (Theresa)

Hey, I developed such sort of small "apron-like" system during the week-end (Ann)

I was sketching such an apron-like dress so that it would fit a small girl. (Theresa)

Figure 5 presents sketches of the members of team B as well as illustrates the final solution that the team ended up with. Ann's and Cathy's designs were based on idea of apron-like dress whereas Theresa experimented with a 'unisex body' for a baby boy in her sketches. Finally, the team decided to produce Cathy's design. The group also appeared to work in a relatively close collaboration although a shared design object did not emerge until the manufacturing phase of the process.

In Team C's design process (Nina, Brita, Carita, and Susan), the members' roles and activities varied considerably. The team was not able to develop a shared design object during the process, and activities of the team members were only loosely coordinated. Nina was most active and produced the main part of the design statements (59%, f=108). Brita produced 48 design statements, and Carita appeared quite passive and produced 25 statements. She commented on other member's solutions and provided some new information from the Internet. Susan hardly participated in the collaborative team process at
all, posting only 3 statements. Nina who used FLE more intensively than the other members of the group, provided a lot of information referring to different information sources. The following transcript illustrates how Nina unsuccessfully tried to activate others to participate in knowledge building and make decisions together.

We have not succeeded in deciding the size of our design object – clothing. This makes designing a little bit difficult. (Nina)

During the last design lesson I suggested that the size would be 30 centimeters (there were already several pieces of the other sizes and designers of small baby's clothes were needed). This need not to be the final decision but we have to make the decision about the size quickly. So please react -- so that we can make the decision. (Nina)

I just returned from the group lesson and the size was decided to be 35 centimeters. Do you agree about that? I do. (Nina)

I addition, we decided that each group should have a shared idea about the clothing being designed, whether it is a shirt, zip-suit, or trousers + shirt (Nina)

WE HAVE TO DISCUSS WHAT KIND OF CLOTHING WE ARE DESIGNING.
PLEASE [GROUP] TAKE A STAND SO THAT WE CAN START THE REAL WORK. (Nina)
In the end of the design process, Nina apparently became frustrated with the others’ lack of response. Since Team C did not make any common decision and, consequently, did not have a shared design object, each of the students produced a very different kind of clothing. However, Nina's and Brita's designs ideas looked very similar, presumably, because they were collaborating more intensively. We may conclude that this team designed in an individual way and did not, according to the evidence gathered, engage in as intensive collaborative designing as the other groups.

Discussion

We examined how FLE-Tools environment supported collaborative designing through organizing a pilot course in which teams of first-year students of textile teacher solved an authentic and complex design task. The students were guided to collaborate by sharing their design knowledge and searching for new information. The present study focused on providing support for further development of FLE’s design tools through detailed analyses of a limited number of cases. Since the study involved intensive investigation of a small number of students, all of whom operated in the new networked environment, the data do not support the drawing of comparative conclusions; in particular there is no direct evidence permitting the assessment of the degree to which students’ performance in the design task performed better than in some alternate context.

The participants of the study attended the first year of textile teacher education, and they had varying levels of computer skills and had no previous experience of computer-supported learning. Nevertheless, the students were very motivated to task, most of them
participated intensively, and they generally found FLE-Tools very easy to use. Further, the pedagogical decision to organize the students in small intensively collaborating groups appeared to support equal participation and productive collaboration. In some other FLE courses in which students have been working as one large group, it has turned out to be very difficult to overcome the problem of managing all knowledge accumulated to the database (Muukkonen et al. 1999). In the present case, the amount of information was manageable.

The qualitative content analysis of the students' productions posted to FLE's database indicated that knowledge produced by the participants represented prototypical elements of design process. The participants' design activity (i.e., composition, construction, and constraints design), for instance, closely resembled corresponding processes revealed by protocol-analysis studies (see Akin 1986, Goel 1995; Seitamaa-Hakkarainen 1997). The analysis suggested, further, that the iterative nature of designing was typical for the participants who generated their solutions through a sustained process of developing and testing of design ideas. As a consequence, classification of the segmented productions — using categories that have emerged from design research — was a rather straightforward process. These findings suggest that collaborative technology may provide new tools for students and designers to share important aspects of their design thinking.

A theoretical model of the design process was implemented in the FLE-Tools environment, and working in such an environment appeared to facilitate expert-like designing in a sense of engaging students in intensive problem structuring and in-depth analysis of design constraints. Cognitive researchers on design process have reported that novices tend to
start generating solutions without going through a very deep problem structuring (Seitamaa-Hakkarainen 1997, Seitamaa-Hakkarainen & Hakkarainen in press). In contrast, the results of this study suggest that by working in a networked learning environment for solving an authentic design task, students’ engagement in problem structuring may be considerably facilitated. In the case of the examined students, collaborative technology appeared to facilitate the conceptual stage of designing through encouraging participants to engage in a sustained process of knowledge acquisition and problem solving focused on determining and responding to design constraints. Participating in knowledge-building discourse in FLE-Tools environment appeared to guide the students to use and intensively search for various kind of information sources in order to determine design constraints and increase their understanding of premature neonates. During the process of information search, the students also learned to confront sometimes quite opposite and (seemingly) contradictory knowledge and reflect that knowledge with their fellow designers. The analysis of students productions’ revealed that they were able to specify relevant constraints of designing clothes for neonates as well as share their knowledge in a way that would not have been possible without the help of the environment. It appears to us – although we do not yet have strong evidence for our claim – that cognitive scaffolding of expert-like designing also encouraged and provided conceptual tools for the students to reflect on their own design thinking.

The environment did not, however, appear to provide equally strong support for composition or construction design although the participants did discuss their visual ideas and their technical realization in FLE-Tools' database. The problem was that the computer tools used did not allow the users to fully share their sketch development process that is a very
important part of designing (Goel 1995; Seitamaa-Hakkarainen & Hakkarainen in press). The students were able only to scan their sketches to Jam Session but not directly to continue elaborating their fellow students' designs. In order to effectively develop another student's visual sketches, the students would need to have access to and skills in using computer-aided design programs. In the present case, the students had neither experience nor convenient access to these kinds of design tools. We temporized with the problem of sketch development by scanning the pictures of students' developing sketches and prototypes to the Jam Session. In any case, being able to see how other students' sketches developed and shared their visual ideas appeared to facilitate collaboration between the students. An important task of future development of FLE-Tools is, however, to develop tools that would allow the users to work, in a more flexible way, to elaborate and share their sketch-development process by using, for instance, programs for computer-aided designing.

The in-depth analysis of three design teams' collaborative designing indicates that there emerged different patterns; some teams collaborated very intensively making joint decisions (e.g., selecting a certain size of baby, determining the type of cloth) that helped to manage design constraints. Team C appeared to proceed more independently, and each student produced her own kind of clothing. Consequently, we may argue that Team A and B worked with more or less shared design objects representing advanced cooperation whereas Team C only coordinated individual efforts of its members (cf., Engeström, 1992). Further, examination of the data indicates that there emerged a fruitful division of cognitive labor between students; some team members sought for and actively provided new information to their team members whereas other students focused on collaborating technical solutions of
the clothes and actively provided new working ideas.

An important aim of the present study was to facilitate direct student-expert partnership, i.e., provide the students with access to authentic expert knowledge and apply it for designing clothes for premature babies. In the present case, however, the students were only able to visit in the hospital and their requests of information were collected and sent to the experts by the tutor. While continuing the FLE project, we intend to facilitate more intensive and on-line interaction between students and experts so that the students would learn to work productively with customers from the very beginning of their studies. It appears to be profitable to engage expert more closely in knowledge-building discourse with the students.

To conclude, the present study indicated that the FLE-Tools environment may significantly foster sharing of design process among university-level teacher-students. However, the findings concerning FLE’s pedagogical effects have to be confirmed by using controlled and more rigorous studies. Further, it is important to create tools and practices that would help students to share not only the conceptual but also actual manufacturing phase of designing. This could happen, for instance, by sharing problems, reflections, new ideas, and evaluations emerging in the process of manufacturing and testing of the product being designed by the means of collaborative technology. Especially important would be to get users of products being designed to join the process from the very beginning so as to ensure that their relevant perspectives are taken into consideration. Thus, a great deal of more research has to be conducted in order to provide adequately support all aspects of
collaborative designing through FLE.

References


CAPTIONS

Fig. 1. Knowledge-building model of designing

Fig. 2. Scaffolding essential aspects of expert-like designing

Fig. 3. The Jam Session –module window (with designs created during the Premature Babies Course)

Fig. 4. The classification schema of the design process

Fig. 5. Illustrations of Team B’s design ideas
Design Context

Defining the Design Task

Creating a Working Idea

Critical Evaluation

Search Deepening Knowledge

Redefining the Design Task

Developing New Working Ideas

Distributed Expertise
Computer-support for …
Computer-support for …

A) Theresa’s sketch

B) Cathy’s sketch

C) Ann’s sketch

D) Final design selected after testing