
RUNNING HEAD: Collaboration Patterns

TITLE: COLLABORATION PATTERNS IN COMPUTER SUPPORTED COLLABORATIVE DESIGNING

DESIGN STUDIES (draft)

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ABSTRACT

This study examined the intensity of collaboration in computer supported collaborative designing. It focused on how ten teams of university level students of textile teaching were able to share their designing process in a virtual learning environment. An authentic task involving clothing for premature babies was used. The study was carried out by employing qualitative content analysis of students’ written notes and sketches posted on the database. The results indicated that the nature and intensity of collaborative designing varied according to three levels: coordination, cooperation, and collaboration. In three of the teams, the design process turned out to be highly collaborative in terms of students developing a joint design object and being involved in an intensive process organizing.

Keywords: collaborative design, computer supported design, design knowledge
The purpose of this study is to analyze university students’ collaborative designing in a networked learning environment for a given real-life task, and to find patterns of collaboration. Collaborative designing means a process of actively communicating and working together in order to jointly establish design goals, search through design problem spaces, determine design constraints, and construct a design solution. Design processes have been intensively studied by cognitive researchers. Designing is generally considered to be a form of complex problem solving, and it is an iterative process by nature. That is, 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.


3 Akin Ö Psychology of architectural design Pion, London (1986)


Recently, some studies have specifically analyzed design processes with respect to teamwork\textsuperscript{2,8,9,10} and analyses of collaboration in networked virtual design studios have been reported\textsuperscript{1,11,12,13}. However, there are many open questions, such as how to define collaboration and determine its intensity. Collaboration may be time consuming and sometimes requires extensive efforts of community building; hence some researchers claim that it is only suited for very particular problems requiring close coupling of the design process and its participants.\textsuperscript{14}

Computer supported collaborative environments for knowledge building provide a promising innovation to facilitate teamwork between designers. A fundamental aspect of these environments is to provide users with tools for posting knowledge productions into a shared working space and provide means for progressive discourse interaction between the

\begin{thebibliography}{14}
\bibitem{13} Maher M L, Simoff S and Cicognani A \textit{Understanding Virtual Design Studios} Springer-Verlag, London (2000)
\bibitem{14} Kvan T Collaborative design: what is it? \textit{Automation in Construction} 9 (2000) pp 409-415
\end{thebibliography}
participants. Productive working with knowledge, which we call knowledge building 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. Bereiter, 2002

In this paper, we examine the role of collaborative technology in supporting designing based upon results from our first virtual studio experiment in using FLE-Tools in a university-level design course involving a project with an authentic real-life design problem. The technical infrastructure of the present study was provided by a networked learning environment, called the Future Learning Environment (FLE-Tools, see http://fle3.uiah.fi developed by the Media Laboratory, University of Art and Design Helsinki, and the Department of Psychology, University of Helsinki. The FLE-Tools were designed to facilitate expert-like working with knowledge and collaborative designing. The study examines university students’ collaborative designing process as it occurred in a complex and authentic design task – designing clothing for prematurely born babies – and explores how students worked in the FLE-environment. {No hypotheses or questions?} {“premature” is sufficient, instead of ‘prematurely born’}

1. Characteristics of the collaborative design process


Cognitive research on design process has, traditionally, examined designing as an individual mental process. However, current cognitive theories are more and more emphasizing the socially distributed nature of cognition\textsuperscript{17} and the role of social collaboration in modern designing\textsuperscript{18-19}. Social collaboration appears to have a particularly important role during the conceptual phase of designing, i.e., during generation and articulation of the design process through searching new information to help determine design constraints and produce a satisfactory design\textsuperscript{12}. An important aspect of collaborative designing is working with shared design objects: through visual representations, conceptual models, tools, and concrete materials\textsuperscript{20}.

Design content consists of two problem spaces, i.e., composition space (visual designing) and construction space (technical designing). The designers move simultaneously in and between composition and construction spaces controlled by the characteristics of the design constraints and design context\textsuperscript{6,7}. Design constraints form the design context by defining, for example, the intended users and their special needs for the artifact and its function \textsuperscript{21}.

\textsuperscript{17} Hutchins E Cognition in the Wild The MIT Press, Cambridge, MA (1995)
\textsuperscript{18} Ferguson E S Engineering and the mind's eye The MIT Press, Cambridge, MA (1992)
\textsuperscript{20} Norman D A Things that Make Us Smart: Defending Human Attributes in the Age of the Machine Addison-Wesley, New York (1993)
Our previous studies\textsuperscript{1,22} have indicated that knowledge produced during collaborative designing in a networked environment represented prototypical elements of design content.

Two main foci of action (i.e., content and process organizing) can be distinguished in teamwork\textsuperscript{17}. Organizing the group process is a major task in design collaboration\textsuperscript{23,24}. According to Stempfle and Badke-Schaub’s study\textsuperscript{24}, 2/3 of design groups’ face-to-face communication deals with the content whereas 1/3 of the group communication aims at organizing the group process.

Engeström\textsuperscript{25} argued that the nature of collaboration is dependent on whether the actors are sharing the same object or not. In his framework for describing types of collaboration, coordination means that actors are carrying out individual tasks without having a shared object whereas cooperation refers to a collaborative process in which the actors focus on a shared problem and try to negotiate a mutually acceptable way of solving it. While the actors engaged in coordination are following a script that regulates their activity without reflecting or becoming aware of it at all, the latter actors transform the script by constructing their own goal of activity. A characteristic of reflective communication – the

\begin{itemize}
  \item \textsuperscript{23} Chiu, M L An organizational view of design communication in design collaboration Design Studies Vol 23. No 2 (2002) pp 187-210
  \item \textsuperscript{24} Stempfle J and Badke-Schaub P Thinking in design teams – an analysis of team communication Design Studies Vol 23. No 5 (2002) pp 473-496
  \item \textsuperscript{25} Engeström Y Interactive Expertise: Studies in Distributed Working Intelligence University of Helsinki, Department of Education, Research Bulletin 83 (1992)
\end{itemize}
highest form of collaboration – is that the actors are not only sharing an object but also organizing their collaborative efforts by developing a shared script of joint activities.

The nature of collaboration is dependent on different degrees of task sharing. *Single task collaboration* is based on each participant’s own view over the whole design problem whereas during *multiple task collaboration* each person is responsible for a particular portion of the design, and most of the messages are related to the management of the project. Students’ collaboration in design projects is usually a combination of these approaches.

### 1.1. Future Learning Environment FLE-Tools

The present study relied on the Future Learning Environment (FLE-Tools, an open source version of a new generation FLE software is available at [http://fle3.uiah.fi](http://fle3.uiah.fi)), which is a networked learning environment providing a distributed database designed to support collaborative designing. The FLE-Tools provided tools for asynchronous work and communication. The main modules of the FLE-Tools included the Virtual WebTop, the Knowledge Building Module, and the Jam Session Module.

The Virtual WebTop was a place for the user to store his or her documents created by standard office applications in various formats. In the background of the Virtual WebTop is
a metaphor of an open office. Accordingly, the Virtual WebTop allowed a student to visit
desktops of other users in the same course.

The Knowledge-Building (KB) Module is a shared space for discussing design ideas, and
tentative solutions generated by the designers. The FLE-Tools environment consists of
modules that facilitate collaborative knowledge building and aid the design process and it
provides ‘thinking tools’ for organizing and structuring these processes. By categorizing his
or her design notes posted to KB Module, the user is guided to specify his or her design
ideas, 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 members of the design team in question.

FLE-Tools contained the Jam Session Module that is designed to facilitate collaborative
designing by 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. 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. In its basic form, Jam Session
provides tools for storing and versioning (i.e., managing versions) of visual documents.
2. METHOD

2.1. Research procedure

The data were collected, according to plan, from a 17-week course on ‘Clothing-design Project for Prematurely Born Babies’, and students were using FLE-Tools environment during the entire design process. The participants in the study included 31 first-year, textile teacher-students (age 19-26) at the University of Helsinki, who had never before been involved in collaborative design projects or used computer-supported learning environments. The project was organized so that the students worked in three- or four-person design teams. The students were instructed to intensively collaborate within their own design team across the whole project. They were further informed that their individual and collective contributions to FLE’s database formed an important aspect of assessment. In addition, the students were informed that productions of each whole group rather than the contributions of individual students were going to be assessed.

The design task was very challenging; the students were asked to design and produce functionally and aesthetically delightful clothes for premature babies. 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 premature babies’ clothing and 2) practical information about functional requirements for
the clothing being designed, from nurses working with premature 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. Each member of the design team designed one individual prototype. 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 the end of the projects, 200 pieces of clothes were produced.

The entire design project consisted of four basic stages: 1) knowledge building and visual designing (week 1-8) 2) prototype making (week 9-11), 3) testing of the prototype in the hospital (week 12-13), and 4) production of the clothing and exhibition (14-17). The students were expected to work independently outside of the design lessons. Table 1 represents the structure of the design course investigated.

**Insert Table 1 about here**

This study is based on an analysis of the students' written productions and sketches posted to the FLE’s database. In this study, we are limiting our analysis to this database, which was produced during the stages of knowledge building, visual design, and prototype making (12 weeks), because the FLE-Tools environment was not used in supporting production of
the clothing. The following analysis of results is mainly based on a qualitative analysis of
the students' design discourse as recorded in FLE’s database.

2.2. Methods of data analysis

The knowledge posted by the students to the FLE’s database was analyzed by methods of
qualitative content analysis in order to examine the nature of their design process. The
entire FLE database consisted of over 350 knowledge-building messages, involving 1256
design statements. The knowledge-building messages posted to the database were
segmented into propositions representing one main idea. Two independent researchers
were used to assess inter-coder reliability of the segmentation. 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 by using SPSSWIN
program. The classification schemata consisted of the three categories: 1) design content, 2)
design thinking, and 3) design process phases. The inter-coder reliability coefficient of
classifying the data across these variables was .89. Figure 1 presents classification
schemata used in this study.

Insert Figure 1 about here

26 Chi M T H Quantifying qualitative analyses of verbal data: A practical guide Journal of the Learning
Sciences 6 (1997) pp 271-315
The first variable refers to the actual design content: 1) *design constraints* (e.g., babies, hospital treatments, parents needs, special properties of clothing and materials), 2) *composition design* (e.g., clothing pattern, size, colors, fabric pattern), 3) *construction design* (e.g., material, structure, technical solutions for sewing seams and bottoms and sewing order). 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. The students used these scaffolds to categorize their design process and corresponding posting to FLE’s database. The present investigators applied the same categories of scaffolds to classify the segmented ideas produced by the students. By specifying design context the design problem was determined (for example *Do the premature born babies turn around while sleeping? Do they lie down on back or on stomach?*). Design progresses by articulating and elaborating 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 commented 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 metacommments, these students assessed whether the design process was progressing in the desired direction, whether appropriate methods were used, how the design task was shared, and what accomplishments were attained by members of a design team (*Shall we come up with a collective way of working or shall everyone do what he or she wants to do, and just let's see what will happen when we meet*).
The design process, phases category was used to assess the students’ participation in the different phases of design problem solving that are generally present in design process. These categories were easily identified in the design statements. The variable consists of 1) problem structuring, 2) problem solving, 3) decision, and 4) process organizing. Problem structuring statements generated the information (e.g., design constraint) that refined the design problem. Problem solving refers to an active process of finding a solution for the design. Decision statements refer to a solution made regarding particular design elements or design sketches. 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 frequently do\(^6\). Further, we wanted to know whether and how the students organized their collaborative activities during their design process. The relative proportion of statements that focused on organizing the team members’ joint activities and efforts of collaborative designing was used to assess intensity of collaboration. Our assumption was that intensive collaboration would entail strong efforts to organize mutual activities of team members and that shared design objects could not be developed without such efforts. The process-organizing variable represented statements that helped to regulate the socially shared process of designing. These included, for instance, statements that referred to organizing design teams’ meetings, sharing tasks between team members, making joint decisions, and practices of working with FLE-Tools.

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Following Engeström\textsuperscript{25}, we analyzed the nature and intensity of collaboration by assessing a) whether and to what extent members of a team shared a design object and b) how much effort they put to organizing the process of their collaborative designing. Sharing of design objects was assessed by examining to what extent the students shared the same design elements and solutions in their visual sketches and prototypes. In some cases, for instance, specific visual design elements, such as size, color, fabric pattern, or elements of technical construction remained similar from one participant to another. On the basis of shared design elements and solutions, the sketches produced by a design team were classified according to 1) \textit{individual design object}, 2) \textit{partially shared design object}, and 3) \textit{completely shared design object}. Two independent coders classified all ten groups’ sketches according to the degree of sharing of design objects \{?\} and agreed in all except one case.

3. RESULTS

3.1. Contents of the students’ design process

The entire database of ten design teams consisted of 1256 design statements. Three teams out of ten provided less than 100 statements whereas two teams produced over 200 statements. During the first five weeks, the students worked independently, building knowledge of neonates, especially those born prematurely, through elaborating their design ideas, sharing new knowledge among their team members, and specifying their design problems. The number of statements increased steadily during eight weeks, and students used FLE-Tools most actively during visual design sessions.
Firstly, we conducted analysis to examine whether the learning environment would facilitate consideration of design constraints in the participants’ designing. The entire database of the design content consisted of 1045 design statements (some statements \( f=211 \) representing mainly process organizing were excluded from this analysis). The analysis revealed that design constraints played a significant role in the students' designing: 35% \( f=369 \) of the design statements dealt with the design constraints. About 36% \( f=377 \) of the statements were considerations of the visual aspects of the clothes (i.e., types of clothing, color, fabric pattern etc.). The construction design (i.e., technical design aspects of the clothes) was handled in 29% \( f=299 \) of the design statements. Most of the teams emphasized constraints and composition design, whereas some of the design teams appeared to emphasize all aspects of designing evenly. These findings indicate that constraint related to the premature neonates and special aspects related to their clothing had a significant role in the students’ designing. Figure 2 demonstrates how the forms of the design content progressed during the 12-week period of designing.

The students structured design constraints actively during the first seven weeks. Visual designing continuously occurred, and the construction design was more emphasized in the end of the design project. However, from Figure 2 we can infer that all design contents were actively elaborated simultaneously from the beginning of the design project.
Students’ notes frequently consisted of statement that represented different categories of design thinking (i.e., working ideas as well as new information). The analysis indicated that as much as 32% ($f=397$) of the statements produced by the design teams represented new information; 35% ($f=440$) of statements represented working ideas; and 12% ($f=150$) of the statements defined the design context. In design-context statements students asked for information about premature babies (e.g., what kind of treatment the babies received, and in what kind of positions the babies sleeps). Figure 3 demonstrates how the various forms of the design thinking progressed during the 12-week period of designing.

The students appeared to acquire new information about the premature babies most actively during the first seven weeks, and the role of the new information decreased steadily toward the end of the project. The students provided and shared new information about premature babies which they found from several information sources, for example, from the internet web-pages, books and research papers, parents of premature born babies, their relatives or experts. The working ideas were directly connected to the design elements, and production of the working ideas increased substantially from the seventh week to the end of the project. The professor’s lectures on visual designing started at the same time (see table 1). Moreover, the metacomments concerning evaluation whether the design process progressed in the desired direction were as much as 14% ($f=181$), and comments as little as 7% ($f=88$) of the statements produced by the teams. The comments were connected to the other students’ working ideas or evaluation of information acquired.
Further, in order to obtain comprehensive information on how the design progressed, the students’ design statements were analyzed in relation to different phases of their design process. The analyzed database revealed that the design teams’ activities were mainly in the category of structuring the design context and new information since 41% \((f=511)\) of the statements posted to the database represented problem structuring activity; 32% \((f=398)\) represented problem solving; and only 6% \((f=75)\) represented decision making. During the decision-making stage, the participants made only very general level decisions; the final detailed decisions were made only after prototype testing. The design teams focused on organizing their collaborative design process in 21% \((f=265)\) of the statements. Figure 4 presents how the design process progressed during the 12-week period.

**Insert Figure 4 about here**

From Figure 4 we can infer that the problem structuring activity was very intensive during the first seven weeks of the course, problem solving started from very beginning but it increased as the problem structuring decreased. In problem structuring phase the students clarified the design context and design constraints, defined requirements for clothing or analysed the needs of the neonate’s parents for clothing. The role of problem structuring in the beginning of the course indicates that the students genuinely expanded their understanding of the constraints of designing clothing for premature babies and shared their cognitive achievement through the database. It is encouraging that the inexperienced students who usually have a tendency to jump directly to solutions, engaged in an intensive problem structuring activity.
The variable for process organizing clearly differed from other variables because the students did not handle any design ideas or design constraints in those statements. Through statements representing process organizing, the design teams developed their shared understanding about how to proceed with the design task. Further they monitored each member’s participation and commitment in co-designing by establishing shared design solutions and working tasks.

3.2. Collaboration patterns

The results highlight various aspects of the collaborative design process and its content across all students working in teams. To better understand the nature of the collaborative design process that the design teams engaged in, we carried out a further analysis of intensity of collaboration. K-means cluster analysis was performed in order to identify groups of teams that would represent the same type of collaboration. The variables used in the analysis were degree of shared design object (i.e., individual, partially shared, completely shared) and the proportion of statements representing process organizing. Three clusters emerged from the analysis; cluster 1 represents coordination, cluster 2 cooperation, and cluster 3 collaboration. Typical of the first cluster was individual design objects and very little emphasis on process organizing. The second cluster represented partially shared design objects and moderate emphasis on process organizing, whereas the third cluster was characterized by shared design objects and a very high proportion of statements representing process organizing. Figure 5 presents each team’s process organizing by shared
object. There is a positive relationship; higher values on process organizing being associated with higher values on shared object.

**Insert Figure 5 about here**

The cluster analysis revealed that three teams (i.e., 6, 9, and 10) were collaborating very intensively by organizing the process and sharing common design objects. Characteristics of six teams that engaged in cooperation was that they organized their joint process of designing less than the teams above, and they partially shared their design objects. One of the design teams (Team 7), however, appeared to have severe difficulties in organizing design process and did not develop a shared design object. In the following, we will briefly describe the various patterns of collaboration modes (i.e., coordination, cooperation and collaboration).

Team 7 (Nina, Brita, Carita, and Susan) was not able to develop a shared design object during the process, and activities of the team members were only loosely integrated. Figure 6 depicts characteristics of Team 7’s coordination. It shows in an abstract way, how all members produced own individual design objects without collaboratively organizing the design process.

**Insert Figure 6 about here**

Nina was most active and produced the main portion of the design statements ($f=108$). Brita produced 48 design statements; Carita appeared quite passive and produced 25 statements.
Susan hardly participated in the team process at all, posting only 3 statements. Nina was only one who produced statements representing process organization (8%; \(f=15\)). The following excerpts illustrate how Nina unsuccessfully tried to establish shared design solutions.

We have not succeeded in deciding the size of our design object – clothing. This makes designing a little bit difficult. 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 22.3. week 8)

I just returned from the group lesson and the size was decided to be 35 centimeters. Do you agree about that? I do. /.../ 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 25.3. week 8)

Since Team 7 did not have a shared design object, each of the students produced a very different kind of clothing. However, Nina’s and Brita’s activities were more intensively coordinated and their designs ideas looked quite similar. After prototype testing, Team 7 decided to produce Brita’s wraparound {garment, shirt} {?}.

Insert Figure 7 about here

In team 8, the design process showed a pattern of cooperation. They had quite a high level of process organizing (27%, \(f=37\)) and they had a partially shared design object. Figure 8 is an abstract presentation of Team 8’s cooperative design process.
In Team 8’s work, Nicole was the most active, providing 66 statements; Ann offered 40; and Patricia produced 33. It was characteristic of Team 8 to negotiate about specific aspects of designs (e.g., piece of clothing, size, fabric pattern, and colors). The following transcripts illustrate how members of the team{?} approached a shared solution to their design task.

...Ok now it is this plan itself. As Patricia said in the beginning, a wraparound (overalls) playsuit could be neat solution. Thus, I have been developing that further in my spare[spare] time. (Nicole 25.3. week 8)

...My [idea] about wraparound (overalls) playsuit is partly double (leg and sleeves cuffs + hood), so the different colors will brighten up the appearance greatly. (Patricia 30.3. week 9)

So my design is pretty much ready and I had the idea to make a wraparound shirt and pants as a prototype. Pattern of the clothes will be very simple. Nicole and I were talking already about that and you [Nicole] said that it does not matter if we not [=don’t] all ...make (overalls) playsuit. (Ann 6.4. week 10)

After visiting in the Department of Prematurely Born Babies, Team 8 decided to design clothing for a 38 centimeters or so, head-to-toe length. Patricia and Nicole made sketches of wraparound (overalls) playsuits. An idea of Patricia’s clothing pattern was combined collar and hood, whereas a hat was part of Nicole’s outfit. Ann designed a wraparound shirt and pants. After all, Team 8 chose Ann’s set of clothes for production.
A characteristic of Team 10’s (Cecilia, Hannah and Tina) design process was very intensive collaboration. Cecilia was most active and produced the main portion of the team’s design statements ($f=107$). Hannah produced 64 design statements, and Tina offered 38. The members were able to develop a shared design object (i.e., there were many similar features in all students’ sketches) and controlled their design process by producing a high number of process organizing statements (35%; $f=74$). Figure 8 is an abstract presentation of Team 10’s collaborative design process.

**Insert Figure 10 about here**

The following excerpts illustrate how the members of Team 10 organized their collaborative activities:

*I have been thinking about those wraparound pants together with apron-type of shirt. I will develop those ideas further. It is difficult to know what you want, so that's why it is important to consider the present situation and to try to achieve shared understanding of the final thing [to be designed].* (Cecilia 24.3. week 8)

*I started to develop very simple kind of wraparound shirt, which you do not have to pull over a head. For[a] smaller baby, this shirt is like a skirt and [for a] more bigger one it is shirt. /.../ It should be advisable to think about the tasks and make some kind of division of labor. Otherwise we will produce 3 pants, 3 shirt and 3 hats!* (Tina 26.3. week 8)

*I figured out that everyone should make his or her own prototype as a whole set of clothing, so it is not enough that I just do the pants etc. Although the situation is this, I designed only pants and made patterns for that and also tried to produce them quickly.* (Hannah 31.3. week 9)
The members of Team 10 designed a uniform set of clothes. They had decided in an early stage of the project to design pants and shirts. The main structure of clothes was decided together, but they made also a decision about task sharing; Hannah concentrated mainly on pants being designed, whereas Tina and Cecilia created two shirts. The two pieces of clothing can be combined with each other. Figure 11 presents the sketches produced in Team 10.

**Insert Figure 10 about here**

### 4. DISCUSSION

We examined students’ collaborative design process and patterns of collaboration through organizing and observing a virtual design course in which teams of first-year textile-teaching students solved an authentic and complex design task. The qualitative content analysis of the students’ productions posted to the FLE’s database indicates that knowledge produced by the students represented prototypical elements of design process. The students’ design content (i.e., constraints, composition, and construction), for instance, closely resembled corresponding processes revealed by protocol analysis studies.

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 was better than in some alternate, perhaps less technologically sophisticated context.

The results of this study suggest that by working in a networked learning environment to solve an authentic design task, students’ engagement in problem structuring may be considerably facilitated. Participating in knowledge-building discourse in the FLE-Tools environment appeared to guide the students to use and intensively search for various kinds of information sources in order to determine design constraints and increase their understanding of premature babies. The analysis of students’ productions revealed that they were able to specify relevant constraints for designing clothes for neonates.

The environment did not, however, appear to provide equally strong support for visualization although the participants did discuss their visual ideas and their technical realization in the FLE-Tools’ database. The problem was that the first year students’ computer skills did not allow them to fully share their sketch development process in the FLE environment. 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 have needed to have access to and skills in using computer-aided design programs. In any case, being able to share visual ideas and see other students’ sketches appeared to facilitate collaboration between the students. An important task of future development of virtual design studios is to scaffold
students’ use of graphics software to help to visualize their design ideas, elaborate and share their sketch development process, and involve themselves in that of others.

The previous studies\textsuperscript{11,24} indicated that activities towards organizing the team processes are related to the collaboration in design projects. In this study, we demonstrated how two independent variables (i.e., shared design object and proportion of process organizing) can fruitfully be used to assess the intensity of collaboration. Simoff and Maher\textsuperscript{11} argued that, in multiple task collaboration, each person is responsible only for a particular portion of the design, and that does not necessarily require the creation of a single, shared, design conception. As we see it, Simoff and Maher’s description of the multiple task collaboration corresponds better to the concept of cooperation, as earlier defined: Cooperation is accomplished by the division of labor among the participants. We would like to emphasize that the creation of shared design objects is an essential element of collaborative designing. However, the essence of shared objects can be different \{from what?\}; designers might have either a shared understanding of design context and all design elements or designers’ separate design elements have to fit seamlessly in order to construct a shared design object.

The present findings indicate a connection between team members’ ability to create shared design objects and their contributions to organize their processes in the FLE-Tools environment. In other words, there was a positive relationship with higher values on shared object being associated with higher values on process organizing through the FLE-Tools environment. The in-depth analysis of design teams’ collaborative designing indicates that
there emerged different types of collaboration. A challenge of collaborative design environments will be to develop tools and practices that would help each design team to engage in very intensive collaboration, share design process as well as the interaction between designers, and jointly develop and elaborate shared design objects.

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 to designing clothes for premature babies. In the present case, however, the students were only able to visit the babies’ hospital without the opportunity, during the actual designing, for discussions with professionals involved in neonatal care; their requests of information were collected and sent to the experts by the tutor. In continuing the FLE project, we intend to facilitate more intensive and on-line interaction between students and experts so that the students learn to work productively with customers from the very beginning of their program. It would likely be profitable for students to engage experts more closely in knowledge-building discourse. 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. Especially important would be to get the users of intended products to join the design process from the very beginning so as to ensure that their relevant perspectives are taken into consideration.

ACKNOWLEDGMENTS
M.Ed. Henna Lahti and Professor Pirita Seitamaa-Hakkarainen designed the study, collected the data, and developed methods used in analysis. Lahti was responsible for analysis of the data, interpretation of the results, and writing the manuscript. Seitamaa-Hakkarainen and Kai Hakkarainen provided theoretical and methodological guidance during the process. Lahti is a doctoral student in the Graduate School of Multidisciplinary Research on Learning Environments. The Academy of Finland and the Finnish Cultural Foundation have supported this research work.
<table>
<thead>
<tr>
<th>Week</th>
<th>Type of activity</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lecture (2 h)</td>
<td>Introduction to the functions of FLE-Tools and the design task</td>
</tr>
<tr>
<td>2</td>
<td>Lecture (2 h)</td>
<td>Lecture by an expert from the Association of the Sick Children’s Hospital</td>
</tr>
<tr>
<td>3-5</td>
<td>Independent work</td>
<td>Participating in knowledge building in FLE</td>
</tr>
<tr>
<td>6</td>
<td>Lecture (2 h)</td>
<td>A visit in the lecture by a nurse who works with prematurely born babies</td>
</tr>
<tr>
<td></td>
<td>Visit</td>
<td>Visiting in the Department of Prematurely Born Babies (1 member/team)</td>
</tr>
<tr>
<td>7</td>
<td>Lecture (2 h)</td>
<td>Introduction to visual designing</td>
</tr>
<tr>
<td>8</td>
<td>Teamwork (4 h)</td>
<td>Visual designing</td>
</tr>
<tr>
<td>9</td>
<td>Teamwork (4 h)</td>
<td>Exploring technical solutions by sewing and experimenting</td>
</tr>
<tr>
<td>10</td>
<td>Lecture (2 h)</td>
<td>Introduction of rational mass-production methods</td>
</tr>
<tr>
<td></td>
<td>Teamwork (4 h)</td>
<td>Visual designing</td>
</tr>
<tr>
<td>11</td>
<td>Teamwork (4 h)</td>
<td>Pattern making</td>
</tr>
<tr>
<td>12</td>
<td>Teamwork (4 h)</td>
<td>Prototype making and testing of the prototype in the hospital</td>
</tr>
<tr>
<td>13</td>
<td>Teamwork (2 h)</td>
<td>Prototype developing</td>
</tr>
<tr>
<td>14-15</td>
<td>Teamwork (8 h)</td>
<td>Production of the clothing</td>
</tr>
<tr>
<td>16</td>
<td>Teamwork (4 h)</td>
<td>Exhibition</td>
</tr>
<tr>
<td>17</td>
<td>Teamwork (4 h)</td>
<td>Evaluation</td>
</tr>
</tbody>
</table>

{I’m not sure about altering your project title, but ‘premature’ is sufficient}
Foci of data analysis

- Design content
  - Constraint
  - Composition
  - Construction

- Design thinking
  - Design context
  - Working idea
  - Comment
  - New information
  - Metacomment

- Design process phases
  - Problem structuring
  - Problem solving
  - Decision
  - Process organizing
HENNA: Taulukoissa labelit pitää capitalisoida eli aloittaa sanat isolla kirjaimella. asiaan puuttui mun kohdalla yksi lehti: kai
Design Process Phases

- process organizing
- decisions
- problem solving
- problem structuring

weeks

0 % 50 % 100 %
Sketch A

Sketch B

Sketch C

Sketch D

NINA

BRITA

CARITA

SUSAN

PROCESS ORGANIZING
PROCESS ORGANIZING

NICOLE

ANN

PATRICIA

Sketch E

Sketch F

Sketch G
FIGURE CAPTIONS

Figure 1 The classification schema of the design process

Figure 2 The design content during the 12 week period

Figure 3 The design thinking during the 12 week period

Figure 4 The design process phases during the 12 week period

{Omit the initial “The”,[1-4] and capitalize accordingly}

Figure 5 Scatter diagram: Process organizing by shared object

Figure 6 The nature of Team 7’s coordination (adapted from Engeström)

Figure 7 Team 7’s sketches

Figure 8 The nature of Team 8’s cooperation (adapted from Engeström)

Figure 9 Team 8’s sketches

Figure 10 The nature of Team 10’s collaboration (adapted from Engeström)

Figure 11 Team 10’s sketches