The Nature of Collaboration in Computer Supported Designing

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Abstract
The purpose of the present study was to examine how a web-based networked learning environment (Future Learning Environment, FLE-Tools) supported collaborative designing. We organized a course in which teams of first-year university level textile students (N=31) solved an authentic and complex design task with the help of the collaborative environment. A problem addressed in the study was to examine beyond the general nature of the participants' design process -- how intensively design teams collaborated and how different teams organized their collaborative design process. The results of the study indicated that the networked environment elicited collaborative designing by helping the teams to share their design ideas and relevant design knowledge. Intensity of collaboration, however, varied between the teams; i.e., members on one team only coordinated their efforts without producing a shared design object; five teams engaged in intensive cooperation by partially sharing their design objects and devoting a moderate proportion of their message content to organizing their collaboration; and, finally, four teams took part in very intensive collaboration by developing a joint design object and engaging in an intensive process organization. A design challenge of FLE-Tools is to develop new tools and practices that would help each design team to organize the design processes and jointly construct, develop, visualize, and further elaborate shared design objects.

Keywords: collaborative design process, knowledge-building environments, shared knowledge

INTRODUCTION
The purpose of the present study was to analyze how university students' collaborative designing may be supported by a networked learning environment. In the present study, collaborative designing is understood as 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 (Hennessy & Murphy, 1999). Design research emphasizes more and more importance of investigating processes of collaborative designing in details (Perry & Sanderson, 1998; Gabriel & Maher, 2000). Computer supported environments for collaborative learning and knowledge building provide a very promising innovation to facilitate collaboration between designers. A fundamental aspect of these environments is to provide users tools for posting knowledge productions into a shared working space and provide tools for progressive discourse interaction between the users (Scardamalia & Bereiter, 1994). The new collaborative technology makes design thinking more explicit and accessible to the fellow designers and enable participants to share their ideas and knowledge and construct joint understanding of design problem and solutions. Through these kinds of collaborative tools, the users are able to rely on the socially distributed intellectual resources in conducting their design projects.

The technical infrastructure of the present study was provided by a networked learning environment, called the Future Learning Environment (FLE-Tools, see http://FLE2.uiah.fi) developed by the Media Laboratory, University of Art and Design Helsinki, and the Department of Psychology, University of Helsinki. The FLE-Tools 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. The FLE-Tools provide tools for collaborative
designing, so that multiple actors can asynchronously work and communicate through discourse and 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. It provides ‘thinking tools’ for organizing and structuring these processes.

The main modules of the FLE-Tools include the Virtual WebTop, the Knowledge Building Module and the Jam Session Module. The Virtual WebTop refers to a personal adjustable display window, which is automatically opened as the user logs onto the system. The Knowledge Building (KB) Module provides a shared space for working together for solving problems and developing ideas and thoughts generated by the users. All KB messages within a project are posted to the shared space, visible as lists of messages. 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 contains also Jam Session Module that is designed to facilitate collaborative designing providing a space for collaborative construction of digital artifacts (see Seitamaa-Hakkarainen, Lahti, Muukkonen, & Hakkarainen, 2000 for a more detailed description of the environment).

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. 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. An important aspect of collaborative designing is working with shared design objects also through visual representations, conceptual models, tools, and concrete materials (see Norman, 1993).

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 to organize participants’ collaborative efforts by developing a shared script of joint activities.

METHOD

Research Procedure

The data was collected 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. In the study participated 31 first-year, textile teacher-students (age 19-26) at the University of Helsinki, who had never before participated in collaborative design project or used computer supported learning environments. The project was organized so that the students worked in three or four students’ design teams. The students were instructed to intensively collaborate within his or her own design team across the whole project. The design task was a very challenging, an authentic and complex design task: the students were asked to design and produce functionally and aesthetically delightful clothes for prematurely born babies. 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. The entire design project consisted of four basic stages: 1) knowledge building and visual designing, 2) prototype making, 3) testing of the prototype in the hospital, and 4) production of the clothing and exhibition. The students were expected to work independently outside of the design lessons. Experts on premature babies participated in the project by providing introductory lectures. 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 order to provide feedback about
In this study, we are limiting our analysis to the 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 study was based on an analysis of the students' written productions posted to FLE's database. In addition, we analyzed students' sketches and prototypes. 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.

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 (Seitamaa-Hakkarainen, 2000). The knowledge-building messages posted to the database were segmented into propositions representing one main idea (Chi 1997). Each segment representing the main meaning was coded and analyzed by using SPSSWIN program. The classification schemata consisted of the following categories: 1) design content, 2) design thinking, and 3) design activity. In order to examine how the students processed design constraints and what was the role of the visual and technical design in their collaborative design process, a variable labeled as design content was used. The variable refers to the actual design content: 1) design constraints (e.g., babies, parents wishes, hospital environment/treatments), 2) composition design (type of clothing, size, pattern, colors), 3) construction design (material, technical solutions for sewing etc). 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.

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).

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, 3) decision phases, and 4) process organization. Each statement was considered to represent just one of these categories. 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 about particular design sketches or group of design elements, not single, design element.

We were particularly interested in whether and how the students organized their collaborative activities during design process. The relative proportion of statements that focused on organizing the team members' joint activities and efforts of collaborative designing (process organization), were used to assess intensity of collaboration. Our assumption was that intensive collaboration would entail intense efforts to organize mutual activities of team members and that shared design object could not be developed without such efforts. Process organization variable represented statements that helped to regulate socially shared process of designing. These included, for instance, statements that referred to organizing of design teams meetings, sharing of tasks between team members, making joint decisions, and practices of working with FLE-Tools. The inter-coder reliability coefficient of classifying the data across these variables was .89.

Following Engeström (1992), 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) completely shared design object, 2) partially shared design object, and 3) individual design object. Two independent coders classified all ten groups' sketches according to the degree of sharing of the design object and agreed in all except one case.

RESULTS

Contents of the Participants’ Design Process

An examination of FLE-Tool’s database indicated that overall the students engaged in rather intensive work in the learning environment. The entire database of these 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 prematurely born 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. 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 consist of 1045 design statements (some statements \( f=211 \) representing mainly process organization were excluded from this analysis). The analysis revealed that design constraints played a significant role in the students' designing: 35.3\% \( (f=369) \) 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., different types of clothing, color, fabric pattern etc.). The construction design (i.e., technical design aspects of the clothes) were handled in 28.6\% \( (f=299) \) of the design statements. Most of the teams emphasized constraints and composition design, whereas some of the design teams appeared to evenly emphasize all aspects of designing. These findings indicate that constraint design related to the premature neonates and special aspects related to their clothing had a significant role in the students’ designing. Figure 1 demonstrates how the different forms of the design content progressed during the 12 weeks period of designing. The students structured design constraints actively during the first seven weeks. During that time they participated in experts’ introductory lectures and some of the students visited in the department of the prematurely born babies and reported their experiences to the fellow students using FLE-Tools. The visual designing was continuously present and the construction design was more emphasized in end of the design project. However, from the figure 1 we can infer that all design contents were actively elaborated simultaneously from the beginning of the design project.

![Figure 1. The design content during 12 weeks period](image-url)
In statements representing design context, students asked information about premature born babies, what kind of treatment these babies receive, and in what kind of position they sleep. The first six weeks consists mainly on structuring the design context. The students provided and shared new information about prematurely born babies which they found from different information sources, for example, from the internet web-pages, books and research papers. The students appeared to acquire new information about the prematurely born neonates most actively during the first eight weeks and the role of the new information decreased steadily toward the end of the project. The working ideas were directly connected to the designed clothing or other design elements and production of the working ideas increased substantially from the seventh week toward end of project.

Further, in order to obtain a comprehensive information 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 were mainly structuring the design context and new information since 40.9% \( (f=511) \) of the statements posted to the database represented problem-structuring activity; 31.9% \( (f=398) \) represented problem solving; and only 6.0% \( (f=75) \) represented decision-making. During decision-making stage the participants made only very general-level decisions; the final detailed decisions were made only after the prototype testing. The design teams focused on organizing their collaborative design process in 21.2% \( (f=265) \) of the statements. Figure 2 presents how the design process progressed during the 12 weeks course.

![The Phases of the Design Process](image)

**Figure 2.** The phases of the design process during 12 weeks period

From Figure 2 we can infer that the problem structuring activity was very intensive during the first eight 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 analyzed the needs of the neonate’s parents for clothing. The role of problem structuring in the beginning of the course 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. The variable for process organization clearly differed from other variables because the students did not handle any design ideas or design constraints in those statements. Through statements representing process organization, 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. In those statements students organized their working methods and shared their tasks, for instance, in a following way:

*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.*

**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 ten teams. 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. To better understand the nature of the collaborative design process that the different 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 (shared, partially shared, individual) and the proportion of statements representing process organization. Three clusters emerged from the analysis. Typical of the first cluster was a shared design object and a very high proportion (30%) of statements representing process organization. The second cluster represented partially shared design object and moderate emphasis on process organization (16%); whereas the third cluster was characterized by individual design objects and very little emphasis on process organization (8%). Accordingly, in the terms proposed, cluster 3 represents coordination; cluster 2 co-operation, and cluster 1 collaboration. Table 2 presents the cluster memberships of each team.

<table>
<thead>
<tr>
<th>Teams</th>
<th>Shared design object</th>
<th>Proportion of process organization</th>
<th>Intensity of collaboration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team 1</td>
<td>2</td>
<td>.19</td>
<td>Co-operation</td>
</tr>
<tr>
<td>Team 2</td>
<td>2</td>
<td>.08</td>
<td>Co-operation</td>
</tr>
<tr>
<td>Team 3</td>
<td>2</td>
<td>.10</td>
<td>Co-operation</td>
</tr>
<tr>
<td>Team 4</td>
<td>2</td>
<td>.15</td>
<td>Co-operation</td>
</tr>
<tr>
<td>Team 5</td>
<td>2</td>
<td>.18</td>
<td>Co-operation</td>
</tr>
<tr>
<td>Team 6</td>
<td>1</td>
<td>.27</td>
<td>Collaboration</td>
</tr>
<tr>
<td>Team 7</td>
<td>3</td>
<td>.08</td>
<td>Co-ordination</td>
</tr>
<tr>
<td>Team 8</td>
<td>2</td>
<td>.27</td>
<td>Collaboration</td>
</tr>
<tr>
<td>Team 9</td>
<td>1</td>
<td>.28</td>
<td>Collaboration</td>
</tr>
<tr>
<td>Team 10</td>
<td>1</td>
<td>.35</td>
<td>Collaboration</td>
</tr>
</tbody>
</table>

The cluster analysis revealed that four teams were collaborating very intensively by organizing the process and sharing common design objects. Characteristic of five teams that engaged in cooperation was they either organized their joint process of designing frequently or partially shared their design objects. One of the design team (Team 7), however, appeared to have severe difficulties in organizing shared design process and it did not develop a common design object.

In the following, we will briefly describe the nature of two teams’ design processes in order to provide a comprehensive view about different practices of collaborating in the FLE-Tools environment. Nina, Brita, Carita, and Susan were members of Team 7 and their roles and activities varied considerably in the team’s design process. The team was not able to develop a shared design object during the process, and activities of the team members were only loosely integrated. Figure 3 describes characteristics of Team 7’s collaboration. It shows in an abstract way, how all members produced own individual design object without collaboratively organizing the design process.

Nina was most active and produced the main part of the design statements ($f=108$). Brita produced 48 design statements, and Carita appeared quite passive and produced 25 statements. Susan hardly participated in the collaborative team process at all, posting only 3 statements. Nina was only one who produced statements representing process organization ($f=15$). The following transcript illustrates how
Nina unsuccessfully tried to activate others to participate in knowledge building and make decisions together.

*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.)

**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.)

In the end of the design process, Nina apparently became frustrated with the others' lack of response. Since Team 7 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 quite similar, presumably, because their activities were more intensively coordinated.

A characteristic of Team 10's (Cecilia, Hannah and Tina) design process was very intensive collaboration. Cecilia was most active and produced the main part of the team’s design statements ($f=107$). Hannah produced 64 design statements, and Tina produced 38 statements. The members actively developed to shared object and controlled their design process by producing a high number of process organization statements. Cecilia produced 36 statements, Hannah and Tina both provided 19 statements representing process organization. In other words, the team was able to develop a shared design object (i.e., lot of similar features in all students’ sketches) during the process and weave team members’ activities closely together. Figure 4 is an abstract presentation of Team 10’s collaborative design process.

![Figure 4. The nature of Team 10’s collaboration (adapted from Engeström, 1992)](image)

The following transcript illustrates how the members of Team 10 tried to organize their collaborative activities.

*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.)

*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.)*

*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. (Hannah 31.3.)*

**DISCUSSION**

We examined how FLE-Tools environment supported collaborative designing through organizing a 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. Further, the pedagogical decision to organize the students in small intensively collaborating groups appeared to support participation and productive collaboration. To conclude, the present study indicated that the FLE-Tools environment may significantly foster sharing of design process among university-level teacher-students. However, this study was explorative in nature and thus the findings concerning FLE’s pedagogical effects have to be confirmed by using controlled and more rigorous studies.

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 (Seitamaa-Hakkarainen, 2000). The participants' design activity (i.e., composition, construction, and constraints design), for instance, closely resembled corresponding processes revealed by protocol-analysis studies (see Seitamaa-Hakkarainen 2000). The participant generated their solutions through a sustained process of developing and testing of design ideas. These findings suggest that collaborative technology may provide new tools for students and designers to share important aspects of their design thinking. Moreover, FLE-Tools 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 2000). 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. 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 that cognitive scaffolding of expert-like designing also encouraged and provided conceptual tools for the students to reflect on their own design thinking.

The in-depth analysis of design teams' collaborative designing indicates that there emerged different types of collaboration. The least intensive collaboration was labeled coordination indicating that students were carrying out individual design ideas without having a shared object and without trying (as a group) to organize their design process together. The most intensive form of collaboration was considered to occur when the actors were both sharing design objects and engaged in intensive process organization together. Between these two extreme forms of collaboration, cooperation took place. It refers to a collaborative process in which the students focus on a partially shared object and devote some effort to control their design process together. A challenge of collaborative design environments will be to develop tools and practices that would help each design teams to engage in very intensive collaboration, share design process as well as the process between designers, and jointly develop and further elaborate shared design objects.

References