Draft of Three Design Experiments for Computer Supported Collaborative Design

Seitamaa-Hakkarainen, P, Lahti, H. & Hakkarainen, K.

Abstract
The purpose of the present article is to examine how virtual design studio environments can be used to aid collaborative designing and describe some of our experiences in supporting collaborative design with such environments. The authors will introduce three design projects. These were projects, respectively, for designing clothes for premature babies, conference bags and tactile books for visually impaired children; they constitute a continuum in terms of being design experiments, each of which highlights certain perspectives on the virtual design process. Our approach, in which the first author was acting as a teacher in each project, made it possible to address current problems faced in the field of virtual designing. The purpose of our design experiments is set up, foster, and investigate an iterative design process, in which previous observations and lessons can be applied to enhancement of educational settings and practices. The authors examined how participants create shared design ideas, to what extent users can be involved in the design process (participatory designing), and how expert knowledge is utilized. According to our experiments, the progressive inquiry model can fruitfully be applied to collaborative designing to facilitate participants’ interaction processes of developing design ideas and sharing their expertise through the virtual design studio.

Keywords
design education, design experiment, collaborative designing, textile design project, virtual design studio

INTRODUCTION

The present investigation began with the observation that design education strongly relies on individual studio teaching and designing, not on intensive collaboration between designers and end-users of the product. The modern design curriculum contains project-based learning as represented by the design project, as its core. However, it is suggested here that virtual design studios (VDS) will provide new possibilities as well as challenges regarding how to facilitate collaborative designing between students, and furthermore, how to support participatory design processes with end-users of the product. In this article, we will introduce design process, in normative terms, as a scaffolded progressive inquiry process. The purpose of the study is to describe continuum of three design experiments to facilitate participants’ interaction for developing shared design ideas and distributing their expertise through the virtual design studio.

The design processes have been studied intensively from the cognitive science point of view, usually as an individual process of solving problems and acquiring individual knowledge and expertise (Akin 1986; Goel & Pirolli 1992; Goel 1995; Seitamaa-Hakkarainen 2000). General to all domains of design are similar open-ended and complex design problems and activities that produce new cultural entities. A design task includes knowledge of external conditions of
designing, and can roughly be seen to answer questions concerning to whom, what, where and by what kinds of resources, is the item being designed. The design task creates a preliminary common ground for designing; suggested solutions carrying the design process forward rely on the designers’ experience and professional knowledge (Akin 1986; Goel 1995; Lawson, 1990; Seitamaa-Hakkarainen 2000). In the design process, a vague initial idea is developed through various sketches (including diagrams, plans, and so on), iteratively, from concrete experimentation and testing of prototypes, toward a final design (Goel 1995; McGown et al. 1998).

The pedagogical models that have been widely adopted in design education are experiential learning, problem-based learning, case-based learning, and studio or project-based teaching (Kolb 1984; Schön, 1987; Akin 2002). One of the starting points of the present study, however, was the knowledge-building pedagogy developed by Professors Carl Bereiter and Marlene Scardamalia in the context of Computer Supported Collaborative Learning (CSCL) (Bereiter, 2002). According to Bereiter and Scardamalia (2003), in a knowledge building approach, knowledge is dealt with in design mode rather than belief mode, or to put it differently, there is deliberate work on knowledge objects, including theories, plans, conceptions and so on. In design mode, students are concerned with the usefulness and adequacy of ideas, and moreover, continuous improvement of ideas is seen to be essential; knowledge objects are developed and refined. In knowledge building, a computer-supported environment is that in which the collaborative work with ideas goes on. Based on the knowledge building pedagogy as well as our previous research concerning design expertise (Seitamaa-Hakkarainen 2000; Seitamaa-Hakkarainen & Hakkarainen 2001) we have developed the model to facilitate design processes and students’ design thinking. The center of the model is distributed expertise and collaboration (see Figure 1). The model emphasizes that the collaboration should occur in all phases of the design process by creating shared design contexts, analyzing design constraints together, sharing new knowledge and providing feedback for the design ideas. The aim was to facilitate the end-users or different domain experts to work together with the students from the very beginning of the virtual design project.

Figure 1. Progressive inquiry model of collaborative designing
In the progressive inquiry model of collaborative designing, it is essential to integrate the expertise of the design team with that of specialized experts related to domain in question, and well as that of prospective end users of the product. The idea is that all participants are working to develop the shared design object by sharing their expertise socially. The question is not simply to divide labor among various parts of the overall design project. The model—a normative one—describes the design process as spiral in nature (approaching satisfactory design iteratively through successive design cycles). The model should not, however, be understood as a description of rigidly prescribed design stages. The process starts from all participants performing a joint analysis of the design task or design context; they have to learn to understand design challenges or the constraints related to the problem or solution. In this stage, the external domain experts and prospective end users have a critical role in defining and determining the various physiological, psychological, and emotional aspects central to the design of the product (i.e., external and internal constraints). During the framing of the design context, various, sometimes conflicting factors that affect the design process and define its requirements need to be taken into consideration. By acquiring deepening knowledge, sharing that knowledge socially, producing varying design ideas and evaluating those ideas the design process progress cyclically forward. One central aspect of the design process is a designer’s way of using a variety of visual representations, written notes, and graphical models for representing, developing, and storing emerging ideas (Goel 1995; McGown et al. 1998), and her way of subjecting these to scrutiny, assessment, and development.

Many investigators emphasize that, by using the new technologies, people can be helped to assimilate knowledge and skills in participating in guided collaborative working, studying, and interacting (Kvan 2001; Hakkarainen et al. 2004; McCormick 2004). The virtual design studio (VDS) has become more common in recent years in various design fields. VDS refers to computer-supported environments or www-based resources that allow communities separated by time and space to work with shared design ideas (Maher et al. 2000). The technical infrastructure of the present studies were provided by a networked learning environment, called the Future Learning Environment (FLE-Tools), FLE2 and Knowledge Forum. These environments provided tools for collaborative designing, so that multiple actors can asynchronously work and communicate through discourse and visual representations in the virtual learning environment. The use of VDS may fail, however, due to pedagogical or organizational barriers. While working in VDS, students face both design challenges and social challenges related to interaction and achievement of mutual understanding. In such contexts, students go through two processes, i.e., learning the design topic in question and learning to productively utilize the VDS (Kvan 2001; Lahti & al. 2003). In this paper, the present investigators will describe and analyze the possibilities of the VDS to support and realize the progressive inquiry process of collaborative designing in three design experiments.

**DESIGN EXPERIMENTS**

The present investigators’ approach to virtual designing represents a research strategy called “design experiments”. Design experiment (also called design-based research) is a series of approaches, with the intent of producing theories and practices that influence learning and teaching in naturalistic settings (Brown 1992; Collins 1992; Edelson 2002). This strategy entails studying virtual designing by creating a series of interventions that facilitate certain aspects of designing and, thereby, transform some prevailing aspects of educational practices. According to Edelson (2002), educational researchers are nowadays more often using interventions as a means of advancing their understanding of educational learning environments. Typical of this strategy is to define research questions and goals according to
results of earlier investigations, initiate certain novel practices, examine what happens, and try
to gradually explain how, when, and why the intervention in question works in practice.

In this article we illustrate how we have carried out our design experiments in order to
develop virtual design studio practices in university-level educational settings. Following the
design experiment approach, the first author’s role as a main instructor in each project made
it feasible to initiate certain novel practices, to develop, reflect and evaluate how the
experiment works in practice. To develop virtual design in design education, the present
investigators had the following objectives: 1) to develop and implement authentic and
meaningful design contexts in VDS, 2) facilitate creation of shared design ideas in design
teams, 3) support participation of end users in networked design processes, 4) provide expert-
support for virtual design process, and 5) create scaffolds for design thinking based on
progressive inquiry model.

The iterative cycle of the design experiments consists of three projects: 1) designing clothes
for premature babies, 2) designing conference bags, and 3) designing tactile books for
visually impaired children (see Table 1). The first two projects were realized as a part of basic
studies of textile teacher-students, whereas the tactile books project was voluntary in nature.
Table 1 shows general objectives, VDS environment used, participants, collected research
data and data analysis methods applied for each project.

Table 1. General description of three design experiments

<table>
<thead>
<tr>
<th>Design project</th>
<th>Central objectives</th>
<th>VDS</th>
<th>Participants and Research Data</th>
<th>Data Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clothing for premature babies</td>
<td>Authentic, genuine and meaningful design context</td>
<td>FLE-Tools; Knowledge Building discussion and shared space for digital artefacts. <a href="http://fle3.uiah.fi">http://fle3.uiah.fi</a></td>
<td>Ten design teams (31 students) FLE-Tools database Questionnaires</td>
<td>Qualitative content analysis: Design thinking; Design process phases; Design content</td>
</tr>
<tr>
<td>Spring 1999 University of Helsinki</td>
<td>Creating shared design ideas in a VDS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conference bags</td>
<td>Participation of end users in virtual designing</td>
<td>FLE2; Knowledge Building discussion with attachments. <a href="http://fle3.uiah.fi">http://fle3.uiah.fi</a></td>
<td>Six design teams (24 students) One teacher, three tutors Eight users FLE2 database Questionnaires</td>
<td>Social network analysis I Qualitative content analysis: Design thinking; Design activity; Co-authoring; Information exchange II Qualitative content analysis: Product characteristics User’s activity</td>
</tr>
<tr>
<td>Autumn 2000 University of Joensuu</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tactile</td>
<td>Expert</td>
<td>KF;</td>
<td>Three design</td>
<td>Qualitative</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In the following sections, we describe each of our design experiments. We have built project descriptions in such a way that we briefly introduce the design problem given, the structure of the project in question; then we summarize the main results of each design experiment. The analysis of the databases in VDS was undertaken in accordance with the principles of qualitative content analysis. The databases were segmented into propositions representing one main idea. Each segment was coded according to the categories presented in Table 1. The more detailed analyses of the design experiments are presented elsewhere (Seitamaa-Hakkarainen & al. 2001; Lahti, Seitamaa-Hakkarainen & Hakkarainen 2003; 2004).

I Design experiment: Clothes for premature babies

The first virtual design studio experiment was the ‘Clothing-design Project for Premature Babies’. The design task was a very challenging, authentic and complex design task: the students were asked to design and produce functionally and aesthetically delightful clothes for premature babies. In the study, there were 31 first-year, textile teacher-students (age 19-26) at the University of Helsinki, who had never before participated in a collaborative design project or used computer supported learning environments. The study focused on examining how the progressive inquiry model of collaborative designing characterizes advancement of designing in a networked environment. In addition, we were interested in how members of design teams develop shared design ideas and organize their collaborative activity within the network environment. The project was organized so that the students worked in three- or four-member design teams. Each student was instructed to intensively collaborate within her own design team across the whole project. The teacher (first author) sent material to the FLE-course information context, but she did not participate in the design teams’ asynchronous interaction. The technical infrastructure was provided by Future Learning Environment (FLE-Tools; see Figure 2). Figure 2 presents discussion thread and shared space for visual representations in FLE-Tools.
Design and production of clothing for premature babies took 17 weeks. During the process, the students had face-to-face meetings and intensive working within the FLE environment. The first stage (weeks 1-8) consisted of knowledge building and visual designing. Knowledge building was supported by a lecture provided by nurses specialized in the topic, and exposure to research literature concerning neonates, in the form of medical articles and photos. After the lecture, interaction with the nurses was centrally taken care of by the teacher so as not to disturb their work too much. One student from each design team, visited the Department of Premature Babies in Helsinki University Hospitals, and each transmitted her knowledge and emotional impressions to other team members through FLE. The challenge in the present case was to find ways to acquire information from the experts (doctors, parents, nurses etc.) about end users (premature babies) and to apply it in the design processes. Thus, the issues and risks related to premature babies constituted the design context and this context was socially created. The students used various sources, for example interviewing the parents and nurses of the premature babies, in order to understand the physiological (i.e., weight and size of the
babies, in what kind of positions the babies sleeps, treatment the babies received), psychological and emotional (i.e., parents feelings and needs) factors related to the design task. Based on acquired information they generated new design knowledge and design solutions (for example special properties for clothing and materials; technical solutions for sewing) for the clothing of neonates. In the second stage (weeks 9-11), students produced a prototype of neonate clothing that was tested at the Department of Premature Babies. Each student initially produced her own design and created a prototype. After user testing, each design team selected one or more designs for serial production. During weeks 14-17, each group finished the design scheme, divided operation of serial production, and produced 10-15 pieces of clothing for neonates.

The first design experiment indicated that successful collaborative designing requires interaction among students relating both to the design task and to the organization of teams’ shared design efforts. The following discussion thread bellow characterizes one team’s interaction in respect of negotiation of shared design ideas and engaging in process organization:

Hi! I will go today, on Thursday, looking for that tie ribbon for the protos. If it is not too expensive I can buy more of that ribbon. (Team C; student C2; week 11).

What do you think if we would buy ribbons with different colors, red, blue, and yellow. In that way we could make the 15 pieces of clothing slightly different from each other. I bought yesterday white ribbon which is actually pretty boring. Today I will go to look for whether there are any colorful ones. (Team C; student C2; week 11)

It appears that the narrow Indian cotton ribbon is not available other than white. Broader ones would be available but those may be too thick when you sew them to be double-sided. (Team C; student C3; week 12)

First about those ribbons. The idea concerning multi-colored ribbons is excellent! And at least there is a hope of finding red ribbon, a member of our course has it. That ribbon is a kind of general article that can be found in every supermarket. Let’s keep our eyes open. I will check during the weekend whether my mother has such colored ribbons in her storage (Team C; student C1; week 12)

The same Team C also managed to create shared design goal so that their prototypes formed together an entire set of clothing; C1 designed wraparound pants that fitted the baby, C2 created a long-sleeved shirt and C3 sleeveless wraparound shirt. The same figured fabric was used in all of the prototypes, and a one-colored tricot formed the lining (see Figure 3).
Advancement of the design process and collaborative aspects of it were examined by analyzing knowledge produced by the participants to the database of FLE-Tools. Students used FLE-Tools actively from the beginning of the design process to the beginning of user testing of prototypes (12 weeks). The database was analyzed according to the nature of design thinking and problem solving pursued, design constraints determined, and design elements defined. During the first weeks, students mostly searched for and shared information concerning premature babies and, simultaneously, socially determined design context. Acquiring deepening knowledge was an essential aspect of the collaborative designing of clothes for premature babies and it was shared to all participants via FLE-Tools database. The database clearly showed the students’ generation of the new knowledge of the design context and application of that knowledge into their own form of design ideas. Qualitative content analysis indicated that visual design elements (such as a model and color of outfit) were processed slightly more frequently than technical design elements (such as seams and clips to be used). By organizing their design process, the teams assessed whether the process was advancing in the desired direction, how adequate the division of labor was, and how well design tools, including FLE-Tools, were functioning.

The first design experiment focused on examining how the progressive inquiry model of collaborative designing, considered in a normative manner, characterizes advancement of designing in a networked environment. It may be concluded that the participants considered solving of the authentic and meaningful design task very important and motivating. Furthermore, the proposed model gave a structural level of facilitation to students’ working: Students’ iterative process of problem structuring, specifying design constraints and searching for and sharing of new information through the shared database corresponded to the model. An examination of the role of new knowledge during problem structuring indicated that the students expanded their understanding of the constraints of designing clothing for premature neonates and shared their cognitive achievement through the database. From the first design experiment, however, emerged new challenges: 1) how to support user-centered and participatory design in VDSs, 2) how to strengthen collaborative generation of design ideas and shared working with digitized sketches from the beginning of the project.

II Design Experiment: Conference Bags

In this second, virtual design studio experiment, the starting point of the project was to examine user-centered and participatory designing in VDS. We ended up asking potential users of the product to take part in the design process even in a very early stage (cf. Popovic
We were interested in to what extent the progressive inquiry model of collaborative designing would help to define and characterize progress of participatory design in the network environment. Moreover, we wanted to examine what kind of role a user comes to have in design process; i.e., whether he or she is a distributor of his or her own experiences or whether he or she performs as an actual team member. Further, the present investigators were also interested in how users and design teams exchange knowledge of functional, expressive and aesthetic properties of the product to designed.

In the project, there were 24 students of textile teaching or teacher education. The design task was to engage in user-centered design of conference bag: *Design and produce practical and aesthetically appealing prototype of conference bag for EuroCSCL conference*. The students were divided to six design teams. In each team, there were two textile teacher students and two teacher students. For each team an avid conference candidate was assigned as users. This allowed the students to interact with users by exchanging questions, ideas and comments throughout the collaborative design process. The design context involved the analysis of the needs of people participating in conferences, possible later use of the bag (multi-functionality of the product), washing and service, temporal and financial resources needed for manufacturing, the needs of potential sponsors and so on. The students worked both face-to-face and within the FLE2 environment, but the users took part in the design process only through the FLE2 environment.

Design and manufacturing of the conference bags took approximately 15 weeks, and it can be divided in four main stages: creating the design context and forming design teams (weeks 1-3), knowledge building and visual designing (weeks 4-6), technical design of the bag, specifying patterns of the product, selecting and testing materials (weeks 7-10), manufacturing and assessing prototypes (weeks 11-15). An expert team assessed students’ preliminary designs at week 6 in another city. Because students did not have an opportunity to meet the expert group, the assessment workshop was audio recorded, and the teacher and tutor of the project summarized the feedback in FLE2 environment. Each group produced its own bag design and manufactured a prototype on the basis of the feedback. At the end of the project, the same expert group assessed all six prototypes created by the teams. Students used FLE2 environment actively from the beginning of design project until production of the prototypes; altogether database material of the project built up across 11 weeks. The users actively took part in the process until week 9.

The user participation in design process was examined on the basis of the database material. The data were classified according to both user activities and product characteristics. The former classification was based on user experiences, their positive and critical feedback, questions posed by users and their design ideas. In the background of the latter classification were functional considerations of the artifact being designed as well as its expressive and aesthetic considerations (Lamb & Kallal 1992). An important criterion of a successful product is an integration of functional and aesthetic or emotional aspects (see also Jordan 1999; Norman 2003).

The analysis of the data indicated that, in the beginning of the process, the users focused on sharing their own user experiences. Later, they actively provided both positive and critical feedback on the students' design and asked them specific questions. The users produced only a few design ideas of their own. They especially highlighted the value of functionality of the product and did not extensively discuss the expressive or aesthetic aspects of conference bags.
The following discussion thread is a typical example of interaction concerning functionality of conference bags mediated by the network environment, between the users and students.

. . . There must be room for small things. You should think carefully what the essential items are; too many pockets make life difficult. I like deep enough pockets where you can attach pens; separate loops for pens are not necessary. A big pocket for personal items. One zipper pocket would be nice. A place for mobile phone. One useful experience is of such a kind of keyloop or hook to which you can easily snap a bunch of keys. Some sort of closing mechanism for the bag would also be useful, preferably one that you can use with one hand. . . (Team 5; user; week 4)

. . . There could be different kinds of pockets; a net-like pocket for mobile phone on one side and a pocket for pens on the other side. On the back side, there could be a plastic pocket for nametag. The size of the pocket could be little larger than business card. There could be more pockets under the flap, at least three, one big and two smaller ones. Pockets’ fastening solutions are under discussion. Ideas are welcome! (Team 5; student; week 5)

Should we increase usability of the bag with a couple of more details???. The users wanted to have a pocket with zipper to the bag. What about putting a zipper into one of the three overpockets, pockets under the flap or actually inside the bag? These kinds of [pockets] would certainly be used for the passport, keys, and other important small things. We could put a loop for keys inside the bag or inside some of the pockets, to which the possible bunch of keys can be easily connected. Is there enough money in the budget for fabric of partition wall? Then it would be easy to separate presentation papers strictly from other conference materials… (Team 5; student; week 5)

In my opinion, there could be at least one pocket inside [of the bag] to which you can safely put your passport (with zipper). There are separate "storage bags" for make-up (not a toilet bag), which at least I am using. That sort of removable thing could be produced to this bag also—for females. (Team 5, user, week 6)

In the analyzed database, there was emphasis on the role of design constraints and experiential knowledge of users. A majority of the users’ messages focused on functional properties of the designed products, such as dimensioning of the bag, pockets, carrying and fastening solutions. The students’ challenge was to respond to the users’ sometimes very conflicting feedback of their designs. The users, in turn, sometimes experienced the interpretation of the sketches difficult, and in one case there emerged wrong interpretations of the students’ sketches.

Participation and role of members of the design teams varied. Usually there were a few team members of the group who kept active contact with a user, whereas other students had more active roles outside of the network environment. Also the users participated with varying intensity and diverging roles. Some users functioned as informants, providing experiential knowledge of conferences that helped to explicate various uses of the bags and understand the needs of the users. Other users involved in the process more actively than just informants by producing some of their own design ideas and providing active feedback of design ideas suggested by the teams. In the latter case, users and teams formed, more clearly, a joint idea of the design.
In this project, investigators used, beyond the database, structured and open-ended self-report questionnaires for students and tutors. These data sources revealed that students experienced receiving good collaborative support for their design work from the users. They also positively regarded the process of sharing their own and their fellow students’ knowledge and productions within the network environment. However, designing of the conference bag was not engaging: students experienced the task to be isolated from their own life world; this appears to have somewhat affected their motivation.

The second design experiment focused on examining how the progressive inquiry model of collaborative designing characterizes participatory design in a networked environment. The proposed model sustained distributed expertise by facilitating students’ and users’ iterative interaction processes of developing design ideas through the shared database. From the second design experiment, however, emerged also new challenges: 1) how to provide expert support in VDSs, and 2) how to create scaffolds for design thinking based on the progressive inquiry model. For the third design experiment, we selected the Knowledge Forum (KF) environment that provided us a possibility to develop scaffold support for design thinking.

### III Design Experiment: Tactile Books

In the third virtual design project, we looked for means of integrating support of domain experts as a part of VDS. The task was to design and produce a tactile book for visually impaired children according to the rules of the European Tactus competition together with Celia Library for Visually Impaired Children. The rules of the Tactus competition formed the design context and constrained the design process. Books suitable for children from 3 to 6-year-old were selected as a competition series. The book was supposed to involve figures that were raised above the background and could be touched; it should be safe for a blind child; it should be adaptable for making of multiple copies. The books were allowed to contain, for instance, plastics, fabric, leather, or fur.

In the project, there were 6 textile teacher students and two students who studied craft-design at polytechnics. The participants were divided into three design teams. The project took eight weeks, and it consisted of weekly lectures, face-to-face meetings and working at KF. The project was voluntary; that affected the participants’ motivation and commitment to collaborative design process. In the course of the project, students were given more specific information on visual disability, the usage and borrowing of tactile books, as well as caretaking and service requirements. Experts on visual disability, craft science and manuscript writing gave presentations concerning the topic in question: they also participated in activities of the design teams through the network environment. A lecture given by people working at the Library for Visually Impaired Children gave vivid images of existing tactile books, haptic properties of the materials involved, and means of producing experiences that affect senses of smell and hearing. The database on Knowledge Forum was linked to various information sources concerning visual disability, and it imported visual material concerning tactile books belonging to the collections of Celia Library.

In the Tactile Book Project, investigators intended to create a design community that had a shared goal. The purpose of sharing of expertise was that experts representing various communities would actively participate in collaborative designing. According to preliminary analysis the experts functioned in the beginning of design process as informants that helped to specify the design constraints. Later on, they also assessed design ideas proposed by the students. Feedback from experts substantially affected further development of design ideas.
Figure 4 presents a view of Team 2’s virtual design. Within this view, one can see the team’s open illustration plan for a tactile book as well as the feedback provided by the experts. The feedback is translated below Figure 4.

Figure 4. Team 2 design plan and visualization of tactile book; bellow expert’s feedback

It appears to me that to this book fits best A4 size at landscape orientation. In that case the cat would fit in the second picture and an entire dog to the fourth. Perhaps, also the sandbox would fit in the form of square into its own page. In the first picture, you may not necessarily need a cat (easier to manufacture!), but the basket could be whole and wind up more and varying types of ball of wool (yarns), not necessarily but if there is sufficient space. The same can be, perhaps, done in the last picture.

Entire figures are easier to understand when examined by fingers. Because visually impaired children are missing the skills of reading pictures that children with normal vision have, change in visual perspective may easily cause a creature to be interpreted as an entirely new creature than that encountered earlier. When I was making my first tactile book, I put a cat, a piggy, a cock, and a mouse seen from behind in one picture because their tails were looking so funny and beautiful. From a teacher of visually impaired children, I got feedback that children did not understood creatures depicted from behind as same that in pictures describing them from the side. Entire figures with all of their limbs are easiest to understand.

A wooden floor in one of the pictures provides material diversity. This is very nice. The wall does not need to be made out of wood, it appears also to be too difficult to implement. To the wall [materials] fits better a material that can be understood as wallpaper.

Knowledge Forum functioned as a forum for sharing and developing design ideas and provided a collective memory of the process. A participant preparing a note in database was asked, pursuant to the goal of knowledge building, to label his or her note by choosing a
Design-Thinking-label (design context, design challenge, my design idea, new information, evaluating idea, organizing process and summary) based on the progressive inquiry model of collaborative designing and from the findings of previous two design experiments. By categorising his or her design notes posted to the database, the user was 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 participants’ design process and share the whole process with the other members of the design team in question.

Prototypes of tactile books produced by students were evaluated at Celia and at the Central Organization of Visually Impaired, and a summary of the assessment was posted to KF. The books were tested also by a 4-year-old child together with her assistant, and this testing/reading situation was videotaped. The students watched the video in order to familiarize themselves with this authentic testing situation and used the feedback to develop the actual books. There were produced, three copies of each book. A design of one team, later on, won a special award at the Tactus competition.

DISCUSSION
To conclude, we have combined essential scaffolds of the progressive inquiry model of collaborative designing and compared these aspects within all three design experiments (see Table 2).

Table 2. Scaffolding Progressive Inquiry in three design experiments

<table>
<thead>
<tr>
<th>Scaffolds of Progressive Inquiry Model</th>
<th>Clothing for Premature Babies</th>
<th>Conference Bag</th>
<th>Tactile Book</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Context and Design Challenge</td>
<td>Hospital environment</td>
<td>Conference</td>
<td>Competition Rules</td>
</tr>
<tr>
<td>New Information</td>
<td>Multiple sources</td>
<td>End-users</td>
<td>Different experts</td>
</tr>
<tr>
<td>My Design Idea</td>
<td>Students</td>
<td>Mainly students</td>
<td>Mainly students</td>
</tr>
<tr>
<td>Evaluating Idea</td>
<td>Students</td>
<td>End-users</td>
<td>Different experts</td>
</tr>
<tr>
<td>Organizing Process</td>
<td>Students</td>
<td>Students and Teacher</td>
<td>Mainly teacher</td>
</tr>
</tbody>
</table>

Firstly, the all three design experiments indicated that it was important for the design process that students and participants construct a coherent design context and specified design constraints by structuring the process iteratively, together. The following design constraints appeared to be relevant to clothing design; varying weight and size of premature babies, requirements of thermal insulation, forms of care provided by doctors and nurses, specific clothing functionality in terms of providing care. Students became aware of these design challenges and provided new design solutions in the form of designing the clothing of prematurely born babies. In the case of the conference bag design, the design context involved the analysis of the needs of people participating in conferences and their desires for later multi-functionality of the bag. Students became aware of these design challenges within the interaction of the prominent users of the conference bags. In the case of the tactile book, it was required to have clear figures that were raised above the background and would correspond to various materials that could be touched. The general requirements for the book came from the rules of the Tactus Competition. In addition, more detailed requirements about the caretaking of the borrowed tactile books (such as cleaning a book; fixing broken parts of the book) were provided by the experts during the lectures and also during network
interaction. In all experiments, the students acquired relevant information about the necessary requirements of the product in question and tried to ensure that the product reflect the end user’s needs. To conclude, there are various ways to implement the user-centered or participatory designing in VDS from very early stages. This involvement increases users’ opportunities to influence the characteristics of the end product.

Secondly, the three design experiments indicated that all of the students obtained and provided new knowledge to the shared VDS space and engaged in reciprocal interaction by answering and asking questions. Students used VDS mainly to collaborate with the users or the experts, but not as actively to work with each other. On the basis of the design experiments, we can conclude that VDSs do not automatically guarantee the collaborative nature of designing; the students’ own active participation and intensive interaction have an essential role in advancement of the process. In the second design experiments, the participants felt that VDS did not provide much added value in interaction between students (who were meeting each other anyway), but it was meaningful interacting with users. Similarly, in the third design experiment, not only did the student emphasize the importance of the interaction with the experts, but he/she also valued the collaboration between team members.

Thirdly, students developed the main part of the new design ideas whereas the participants representing users or experts actively provided their experiential knowledge and evaluated students’ design ideas. The users and experts’ active feedback was essential to promote students design process. In addition, the feedback from the prototype testing situations, in the cases of designing clothing for premature babies and tactile book, had a very substantial role for students’ design progress.

Finally, the collaborative design process is not just designing the products but also designing the process itself, jointly. VDSs function as a shared working space for many participants and allow collaboration between design teams across temporal and spatial distances. However, the success of the joint undertaking also requires active organizing of the collaborative process. Thus, each team also has to make some kind of division of labor and decide who is responsible for certain issues. This requires that some person(s) be responsible for organizing the design process, just as some are focused primarily on advancement of the design itself.

CONCLUSION

The aim of the paper was to explore how, when and why virtual design studio environments can be used to aid collaborative designing. However, it is not simple to give direct recommendations concerning how to conduct effective virtual design studios. Regardless, in constructing design experiment settings, three main components need to be considered carefully i.e., practices, participants and tools. However, if one component is changed in the educational setting, it naturally has an effect on the other components. To transform the students learning experience to better accord with design knowing and design practices, we need to integrate authentic design tasks with social creation of design context. The effective collaboration should be directed so that students learn to adequately use virtual tools and interaction. The role of face to face design situations and the role of virtual design tools need to have a clear purpose and that purpose should be carefully explained to the students. The idea of the three design experiments described above was to find and develop the best practices and tools for supporting the participants’ effort to build up shared design objects.
Even though all the design experiments were very successful in many ways, the students collaboration with each other in the virtual design studio needs to be facilitated further.

Based on our experiments, the practices that support effective VDS was based on the progressive inquiry model of collaborative designing. According to our experiments, the progressive inquiry model can fruitfully be applied to collaborative designing. The teacher can use the model for reflection of the design process; they can reflect and evaluate how the collaborative design process has proceeded; how the shared object is developed and how the process is organized together. The students can be shown how the use of a model can be beneficial to them 1) how important is the gathering of relevant information from different sources and 2) how to ensure that the information needs of the problem are addressed during the design process by the teamwork or through participatory design.

Virtual work processes of expert communities rely on collaborative knowledge-building, methods of team working and collective designing. The teacher of the design project has to consider who are the key stakeholders related to design task or design context, how is it possible to create multidisciplinary design teams and how to get end-users or different experts to participate in developing shared design objects. Moreover, it is important to take into account how to take students' varying expertise and disciplinary backgrounds into consideration in setting design tasks and defining the design artifacts. It may be productive to deliberately create design teams with heterogeneously distributed expertise.

Finally, the VDSs provide novel possibilities for developing the processes of learning and instruction. It is essential not to use VDS only for transmitting knowledge to students, but also to facilitate students' engagement in collaborative building of knowledge. Groupware and virtual learning environments have opened possibilities of organizing shared activities, sharing knowledge and achievements, in addition to the creation of new knowledge and understanding. These tools provide new resources for transforming individual insights and accomplishments into an externalized and public form so that they may become objects for development, items of collective property. However, it is also important to consider how to utilize a database created by an earlier project in a new design context so that new students can build their process on the basis of the achievements of former students.

References


FLE-Tools, see http://fle3.uiah.fi. Developed by the Media Laboratory, University of Art and Design Helsinki, and the Centre for Research on Networked Learning and Knowledge Building, Department of Psychology, University of Helsinki.

KF, see http://www.knowledgeforum.com Developed by IKIT Institute for Knowledge Innovation and Technology. University of Toronto, OISE.