A Constructivist Approach to Information Systems Teaching: A Case Study on a Design Course for Advanced-Level University Students

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ABSTRACT

Constructivist educational methods have been used for decades especially in disciplines with a practical bent: medicine, architecture, engineering and technology. In this paper we examine how information systems design learning could be improved by constructivist methods. We focus on a single information systems design course, where the students, divided in groups, choose one from three alternative design assignments per group. The assignments are supposed to follow closely the process of a real-world design project, ending with a prototype and an evaluation of other groups' prototypes. We witnessed the students' dedication to their work and their appreciation of the fact that the assigned problem came close to a real-world problem, but also the time-consuming nature of teamwork and occasional problems with free riding. We used widely various electronic teaching tools but in the end we believe that the most significant further improvements will come from intensified peer support and instructor guidance to individual teams.

Keywords: Technology Education, Constructivist Learning Methods, User-Centered Information Systems Design

1. INTRODUCTION

A typical information systems (IS) university curriculum lies at the crossroads of several more established university disciplines: IS graduates are expected to master both business problems and information and communication technology (ICT) developments (see e.g. Cappel, 2001). Studies in other fields, such as organization studies, sociology and psychology, are also popular complements. Within the IS studies, the design and development of information systems is a focal point of professional training.

As a rule, education is supposed to teach practices and activities required in the real world. Nevertheless, traditional education is often accused of teaching things in a way that students find it difficult to apply their knowledge to the complex problems of everyday life (Tynjälä *et al.*, 2001). Constructivist learning theories have sought to create learning environments that come closer to real life environments. As a result, constructivist educational methods have long been applied especially in medicine, engineering and architecture. Knowledge in modern constructivist learning theories is seen essentially as a social phenomenon; a social construct. Because the learner builds on his prior knowledge and beliefs as well as on the knowledge and beliefs (and actions) of others, learning needs to be scrutinized in its social, cultural and historical context (Piaget, 1975, 1982; Vygotsky, 1969; Leontjev, 1977; Engeström, 1987; Tynjälä, 1999; Järvinen, 2001). The constructivist approach suits admirably to technology learning, too, because technological knowledge is created rather than discovered. According to Järvinen (2001:40-41), learning *about* technology or/and *through* technology supports "naturally" learning by manipulation (e.g. trial and error), comparison and problem solving in a non-prescriptive real-world-like context that leaves room for creative thinking and innovation.

Recent research literature indicates that there is a fairly clear consensus on the central features of modern constructivist methodology (see e.g. Järvinen, 2001; Tynjälä, 1999; Ahtee & Pelkonen, 1994; Johansson, 1999; Poikela, 2002). The central features of a constructivist learning environment are as follows:

1) *a larger goal* that organizes smaller tasks into a sensible whole (e.g. Pehkonen L., 1994)
2) *ownership of the problem* so that the learner will be motivated to try to solve it
3) *the problem is close to a real world problem* (see e.g. Kanet & Barut, 2003:111; Leino, 1994).

4) *many possible solutions to a problem*
5) *the learner has the main responsibility for gathering knowledge*
6) *the learning environment should be similar to a real-world environment* (see e.g. Lehtonen, 2002)
7) *building on the learner's prior knowledge and experience* (e.g. Pehkonen E., 1994; Ahtee, 1994; Haapasalo, 1994)
8) *room for alternative individual learning strategies*
9) *opportunities for social interaction and cooperation*
10) *communication with peers and outsiders encouraged*
11) *iterative learning process*
12) *guidance should be provided* (see e.g. Björkqvist, 1994)

In this paper, we use the case study method to examine a design course held in Finland for international advanced-level IS university students in order to understand how constructivist learning methods support learners. The course participants worked in groups of two to three members to solve one of three optional design problems (an info kiosk, a mobile system for tourists and a university web platform): they were asked to construct a prototype and evaluate other groups' work. We analyze the students' progress, how they conceived the result of their work, and what they actually learned from it. We are also interested in the group dynamics, the communication and interaction within the group and between the groups, and the support provided by the facilitator. The data was collected by two questionnaires and interviews with the students and the teacher.

2. METHOD

We use the case study method, focusing on the learning situation of one advanced-level university course with 26 students from two universities and one research institution. The case study method belongs to qualitative research methods (see e.g. Alasuutari, 1995), aiming to gain insights rather than gather statistically significant evidence. The case study method allows the scrutiny of a greater number of variables and enables one to follow up interesting, and perhaps unforeseen, observations in great detail. Consequently, in the case at hand the aim is to deepen and broaden our understanding of technology learning based on constructivist educational methods through one well-documented instance. The case study method is nowadays routinely used in technology learning research (see e.g. Yin, 1994).

Two questionnaires and a round of semi-structured interviews were used to collect data. The students were first given a questionnaire in which they assessed various aspects of the course: the learning materials, teaching, the amount of work, the learning objectives etc. After a while they were given a second questionnaire with three multiple-choice questions and 16 open questions, and a chance to write their thoughts in free text about any aspect of the course they felt to be important (see Appendix 1). For the interviews, five subjects were selected. The interviewees were selected so that they would form the best possible cross-section of the students participating in the course. The interviewees included both males and females, students from two universities and one research institution, Finnish and Swedish speaking as well as foreign students, researchers and non-researchers, experienced in User-Centered Design (UCD) and inexperienced in the UCD. By using semi-structured interviews we sought to ascertain consistency and the representativeness of results in relation for instance to student groups. At the same time it was possible for informants to come up with viewpoints and ideas we had not anticipated, and, for us, to follow up these viewpoints. The interviews lasted from 45 minutes to one hour and a half. In the course of the interviews we fine-tuned our questions, thus letting findings guide future data collection (Glaser and Strauss, 1967).

3. COURSE DESCRIPTION

Companies seek to deliver products and services, which are affordable by the many and highly customizable. Likewise, information technology design teams strive to increasingly involve users in the design process. Nowadays, user-centeredness is a must (Downey, 2003). User-centered IS design work is articulated around three main principles: user focus, measurable usability (evaluation) and iterativeness (Gulliksen *et al.*, 2002). Iteration is comprised of the following steps: (i) to understand and specify the context of use; (ii) to specify the user and organisational requirements; (iii) to produce design solutions; and (iv) to evaluate designs against requirements (Figure 1).

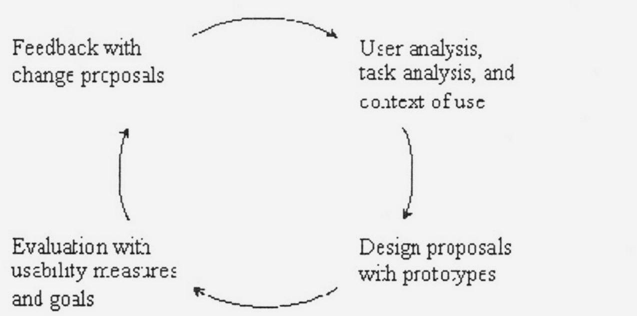

Figure 1. Iterative user-centered design process (adapted from Gulliksen *et al.*, 2002)

In the case of design-oriented courses, it is important to note that (i) there are few university programmes with a primary focus on the user-centred design of IS; (ii) most course literature available is presented in the form of a repository of design methods and techniques – design process orientation is by and large missing (cf. textbooks on human-computer interaction; and Rosson *et al.*, 2004; Leventhal *et al.*, 2004; McCrickard *et al.*, 2004). The structure and goals of the course under scrutiny in this paper reflect the idea that a course in IS design should be process-oriented and give the students an opportunity to apply relevant design methods and techniques to a real world problem.

"User-centered design of information systems" is an advanced level course targeted mainly for advanced and postgraduate IS students, but it has also attracted students from other disciplines, such as computer science, business administration, psychology, geography and linguistics. Altogether 26 students participated in the course under scrutiny. The students are mostly undergraduate and doctoral students of information systems in Finland.

The learning objectives of the course are: (i) to learn about and to apply the process of User-Centered Design to a real-world design project; (ii) to learn about the topics of Human-Computer Interaction (HCI) and interface design principles, which support User-Centered Design; (iii) to enable students with a background in IS to usefully incorporate user and usability requirements when designing and developing information systems; (iv) to aid creative designers of IS to understand, require and optimize usability of the systems introduced in organizations.

The course ran over a period of 10 weeks, comprising course work and evaluation. The course layout allowed the students attend contact teaching sessions through 14 lectures of 90 minutes (two lectures per week), one guest lecture and one design workshop of 90 minutes. Lectures were given on topics with direct relevance to UCD, the course project, and classroom assignments. The guest lecture was given towards the end of the course with the intent to present a holistic view of user-centered design on the basis of a public organization case study. The design workshop was organized before the deadline of the course project. The workshop's core idea was to involve students in a problem-solving situation: the students had to think about the design of a particular system and to propose design solutions in a limited amount of time (90 minutes). A second objective of the design workshop was to engage students in a "warm-up" session before they would start designing the actual prototype.

After the prototype was ready, the students were asked to present their course project (2 sessions of 90 minutes: 20 minutes per group). The purpose of these sessions was twofold. First, to enable the teacher to pre-evaluate the work done so far and ask project-related questions to the group (issues that were not covered by previous teacher feedback), and check how much previous feedback had been taken into account and had influenced the final product. Second, to give the students a chance to see other groups' projects and ask relevant questions for the purposes of cross-evaluation (which is the second course assignment).

During the course, the students had access to several information sources: the course self-study materials, the lecture notes, the lecture readings, and the web sources. The course self-study materials includes an introduction to the topic, the working principles and methodology, the main foundations and conceptual frameworks, methods, techniques and tools. It is in text document form and made available to the students via the course web site. Most of the materials is covered during the lectures (the students are asked to read certain chapters before the lectures, where the topics are explored in further detail; study the examples given and the class assignments completed in the classroom). The lecture notes are multimedia presentations of the course lectures. The lecture readings are selected online articles, to be read before lectures, and distributed by the teacher. The readings are chosen on the basis of how they complement the original study material, for example, an illustration of a design method by a company's best practices, or a design case study. The readings serve as a basis for classroom discussions, where the link between theory and practice is outlined. A collection of links to sources available on the web was provided on the course web site. The nature of the links varies from a broad repository of relevant course topics to focused techniques and design software tools.

Although the course was not specifically planned as a virtual course, a number of electronic communication tools are used to facilitate communication between the students, the teacher and the groups. The teacher uses the electronic bulletin board to publish course information. The bulletin board is also available to students to submit course feedback and questions to the teacher anonymously. The teacher uses e-mail to communicate with the class, with specific groups or with individual students. The students use e-mail to communicate with the teacher, and to coordinate their own group work.

The course project consists of two parts or stages: the design of the prototype and the evaluation of the prototype. First, the students choose one among three different types of systems (a mobile guide for tourists, a university department website, and an information kiosk). They use relevant user-centered design methods to design a prototype of the system. Second, they evaluate one of their peer group's prototypes. The evaluation shows them alternative solutions to the same design task, and helps them to find ways to improve both their own and their peer group's work.

The students were given a chance to get guidance at several occasions during the course project. A work schedule for delivering the prototype was presented by the teacher, and it was made clear that the students were free to choose whether to follow it or not. Along this schedule, the teacher had set four checkpoints at which the students could submit any piece of work for feedback and guidance. Checkpoints help students set pace to their work progress and provide the teacher an opportunity to check how work is progressing and eventually to support groups which seem to be going astray in their work.

The deliverables of the first part of the course project were a so-called low-fidelity prototype, and a report explaining how the prototype has been constructed. The evaluation work, which was the second part of the course project, consisted of the usability evaluation of another group's prototype. Students were free to choose any usability evaluation method they thought was appropriate. The materials that the students used to perform the evaluation were the prototype and the report. The students also attended the other group's prototype presentations. During the presentations the students had the possibility to ask questions regarding the prototypes. The students were asked to compare other groups' prototypes with their own prototype, and suggest improvements.

Figure 2 below shows how the different learning elements relate to each other during the course time period.

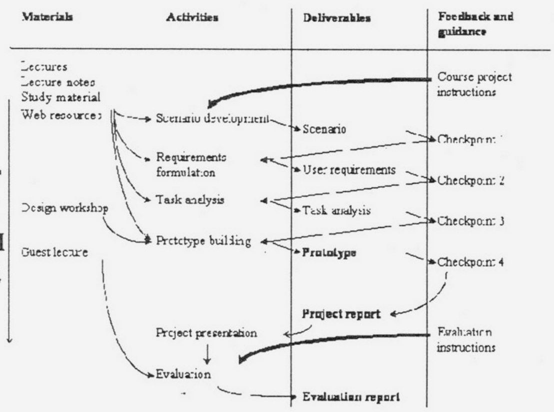

Figure 2: Course layout

4. ANALYSIS

A problem of some kind is a central element in a constructivist learning situation. Educationalists also speak of problem-based learning, which is generally regarded as part of constructivism. Problem-based learning differs in some ways from so-called problem-oriented learning and learning by problem solving. Problem-oriented learning may be conducted entirely by traditional means because problems merely guide the choosing of learning topics and methods. Problem-solving focuses on teaching students rational problem-solving techniques like optimal linear analysis. A problem-based learning situation means that the students have ownership of the problem and that they take responsibility for finding information. The problem may have several different functions. It may act as a trigger, a scenario or a structured starting-point for the students' activities (Poikela & Nummenmaa, 2002).

In this case the problem could be characterized as having two roles: at first it was a scenario because the students were given freedom to choose from three design assignments: an info kiosk, a mobile system for tourists and a university web platform. The students we interviewed mentioned that it was important for them to get to choose (they usually chose the project they felt was the most interesting), as they would commit to the project (appropriation of the problem). Having chosen the design assignment, the problem took the form of a structured starting-point because the students were provided with an optional work order and a collection of optional methods and tools. The students experienced that they had ample leeway in how to approach the task assignment, at the same time appreciating the support provided for them in the form of alternative tools and methods.

It seems clear that the students took responsibility for the design, and felt that the problem came close to what they are supposed to deal with in their professional work after graduation: 73.7% agreed or strongly agreed that course work came close to the real world. Our students generally appreciated the fact that the course covered one iteration of a design process lifecycle: design plan, design work, prototype, and evaluation. Testing the prototype was not included. All in all, the students felt that the project's starting point was "open" and that there was enough room for creative design work.

According to the students, compared with a written exam, for instance, the learning process was more profound and had a lasting effect, owing, among other things, to the fact that they had a chance to put the things they had read immediately into practice. However, Johansson (1999) has observed in his empirical study that in constructivist learning the learners had more positive experience of their own learning results but did not perform better than the control group when their knowledge was tested in a written exam. One wonders whether a traditional written exam is the best means of measuring the learning results in this case. Moreover, increased confidence in one's own skills is a valuable teaching goal by its own right.

There are clear individual differences between the students in how they experienced the course framework. Some interpreted the course structure with its suggested work order and the checkpoints as something, which they had to follow (see Appendix 2). Nonetheless, the students were told that they were free to progress in their own pace and that the checkpoints were optional, not compulsory. The fact is, however, that very few chose to change the timetable and work order but followed the suggested framework. When asked why, the students usually said that sticking to the work order and timetable that had been laid out for them ascertained that they would finish the project in time. There were also few students who said that they were so lazy that they would not do anything without outward control.

We noticed that those groups, which had one or several more experienced and mature members, were more daring in selecting and applying the methods as well as in their final design. In general one can assume that given the relatively large amount of work that students have to perform within a rather tight schedule during a term, they were not too eager to explore alternative avenues, like more unusual methods, and so forth, in their design work. Especially in the beginning – the planning stage – the students spent very much time for this particular course work. One interviewee commented that while they were working long and hard on the project in their student guild office, their fellow students asked whether they had got financing for it. Towards the end of the project the groups spent less time for it as the realities of everyday life set in. The students as a rule observed that there was no end to the amount of work one could actually spend on the project, and one just had to sober up.

It is common knowledge that lectures may sometimes have primarily a social role, making the learners members of a community and motivating their work efforts. Here the learners were advanced-level students so the social role of lectures was not of primary importance. Lectures were generally appreciated as something, which gave support and offered a ready source of theoretical tools at different stages of the project. A few very advanced students preferred to use a textbook, which contained the same information in text form. The web links to practical instructions and examples were regarded as helpful, too. Perhaps a little surprisingly, the students felt writing the report to be important, and not something extra. As one student put it: "In the real world we write documentation".

As was mentioned above, the students chose their design task out of three alternatives, and first after that decision they started thinking about the group. Forming the groups did not seem to follow any clear pattern. Individuals joined together to form a group for very different reasons. Usually individuals sought to join people who they knew from previous study assignments and with whom they had had good teamwork experiences.

The students found teamwork useful and exciting mainly because new ideas emerged, and the work could be divided between the team members according to each one's special skills (see Appendix 2). On the other hand, different ideas and opinions led to disagreements and long discussions so that work in a team was time-consuming. As a rule, the groups did the design work face to face, discussing democratically different ideas. In the students' opinion, the suggestion backed up by the best arguments generally won. The written parts of the work were more often divided between the team members and towards the end of the project also other tasks were more readily divided and done individually, and then attached to the body of the work.

Constructivist learning is known to require more guidance and feedback than more conventional methods (see e.g. Björkqvist, 1994, p. 23). The students got feedback especially at checkpoints, after they had finished some stage of the project (see Appendix 2). As the sample responses indicate, the feedback was generally considered helpful. The feedback was mostly positive so that the students rarely had to make big changes to their design. It seems that the students would not have minded more stringent criticism as they had themselves detected shortcomings overlooked by the teacher. However, the teacher did not point them out, and they usually let them stand as they were. On the other hand, the students said that in several cases the criticism guided the work back to the right track.

Contrary to conventional teaching that underlines pure mental activity, constructivism encourages the use of tools. In our teaching case the students used many electronic and other tools in communicating their design ideas: e-mail, cell phone, peer-to-peer communication software (ICQ), design software, drawing board. However, the face-to-face meetings had the most central role, and many students assessed that most of the time was spent in meetings. At the meetings some teams used, among other things, digital cameras and a video gun to share and discuss design ideas. As a rule, the students were adept at using various technologies for communicating, and it seems that one way of making course work more effective would be to make these tools more readily available to all teams (see e.g. Alavi & Leidner, 2001).

There were clear differences between teams both in the scope and depth with which the various technological tools were utilized. Some communication tools were provided by the teacher: an anonymous electronic discussion forum was proposed to be used as a course feedback communication channel but it was never used by the students. A shared group folder could have been used to facilitate communication between the students and the teacher: the benefit of such a folder would be (i) to provide a place where the students can share their documents, and (ii) to provide a place that the teacher can visit on a regular basis to evaluate the work done by the students and to provide feedback. It is to be noticed that most students used the tools made available to them but rarely took the initiative to use new tools which could have enhanced their work practices.

The above table summarizes the most salient points made so far: how the constructivist learning features (1st column) tallied with the technological and educational instruments used in this particular course (2nd column), and our insights into whether, as well as to what extent, the course attained the constructivist ideals of learning (3rd column).

5. DISCUSSION

The students suggested that the groups could meet at a fairly early stage (e.g. after the presentation) to discuss the designs with their peers, and the discussion should take place without the involvement of the instructor. This observation led us to think that the course framework had not fully utilized the peer support aspect of constructivist methodology. For instance Mayes (2000:9) has pointed out the need to maximize peer dialogue through collaborative means, and here the collaborative means could be discussion sessions between two or three groups who share the same design task. The students clearly expressed their desire for discussion between groups, so an incentive for discussions seemed to be present. Taking our cue from Hardaway and Scamell (2003), one way of making each group's work more readily accessible to others would be to have each team make their own project home page.

Opinions on the usefulness of lectures, lecture notes and web sources differed much. We interpret this so that people have very different individual learning strategies. Especially the lectures divided opinions. Some students considered them the most useful and some the least useful. One way of improving the course would be to tape the lectures. This would leave the teacher, or rather, the facilitator, more time for giving feedback and guidance, which many students found wanting. On the other hand, constructivist educationalists have pointed out the risk that too "efficient" instructor guidance or help from more advanced peers may make some individual learners overly dependent on support, killing their own initiative (see e.g. Tynjälä, 1999; Portimojärvi, 2002).

Table 1. Constructivist Learning Features, Technological and Educational Instruments, and Insights

Constructivist learning features	Technological and educational instruments	Insights
Problem-orientation (features 1-4)	Choice between alternatives	Students appreciated their freedom of choice: target and tools
	Start with a problem	Students took responsibility for the design
	Real-life problem	Promotes commitment
	Open	Room for creative design work
Individual learning strategies (features 5-8)	Suggested work plan	Gives support and direction
	Checkpoints (optional)	Checkpoints as deadlines or support
	Alternative tools and methods	Conservative use of tools
Communication (features 9-10)	Electronic communication tools	E-mail was used the most Discussion board not used
	Teamwork	Face-to-face teamwork appreciated Free democratic discussions appreciated Free riding occurred occasionally Teamwork time-consuming
	Lectures	Source of support and theoretical tools at different stages of the project
	Internet	Web sources were helpful
Learning support (features 11-12)	Feedback	Feedback could have been more stringent Task/group home page required
	Web sources	Prior guidelines important Individual differences in use
	Checkpoints	Checkpoints motivated students
	Peer-to-peer	More peer-to-peer and communication support required Closing section required Task home page required

Some students felt that the evaluation (presentations, report, cross-evaluation, evaluation) was a bit too excessive while others appreciated the chance for self-criticism. In general the students experienced the cross-evaluation as an eye-opener because they saw solutions that differed greatly from their own. "I had no idea that one could see the matter so completely differently than we," said one student when she saw other groups' prototypes.

On the one hand, it is generally assumed that teamwork is improved when the groups are heterogeneous, that is, the members have differing backgrounds and skills (see e.g. Kanet & Barut, 2003, p. 104). On the other hand, the case at hand shows that heterogeneous groups spend much time on coming to terms on working methods, the division of labour, decisions and other aspects of the course work. The team work and the final product might have been better if there had been set more strict requirements for prior knowledge and experience of the subject matter (see e.g. Dineen, 2002).

Especially some groups' work revealed poor knowledge of the technological infrastructure. Adding a separate assignment, to be handed in before the actual design work, in which the students describe the state-of-art of their chosen devices and services, could amend this shortcoming. Additional work seems a feasible solution because the amount of course work was found to be moderate or just right. A few students even said that the amount of work was small compared with many other courses.

The design solutions were generally deficient in the business aspect of the final product. Few groups had seriously and in detail worked out a business model. The course structure could have a section, a checkpoint, in which the business model is assessed. The report, too, could have a separate section on business issues.

One problematic feature of teamwork is the occasional free rider phenomenon. There always seem to be team members whose contribution is low or sometimes nearly nonexistent. Even if the instructor would detect something, it is difficult for him to intervene.

To sum up, the students were dedicated to their work and appreciated the fact that the assigned problem came close to a real-world problem. One way of making the course even more practically oriented would be to involve an IT company. The students felt that the best thing about teamwork was the emerging of new ideas. On the other hand, teamwork was also time-consuming and there were occasional problems with free riding. Various electronic teaching tools were used to enhance learning and communication but in the end it seems that the most significant further improvements will come from intensified peer support and instructor guidance to individual teams. One last observation is that despite "excessive" evaluation the present course structure seems to miss a proper closing section in which the students and the teacher could discuss the design solutions in more depth and reflect upon the lessons learned.

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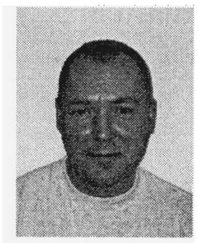

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Appendix 1: Course evaluation questionnaire.

User-Centered Design of Information Systems

1. Which source of information was the most useful?

Lecture notes [ ]
Lectures [ ]
Guest lectures [ ]
Course literature [ ]
Web library [ ]
Other web sources (company web pages, university web pages etc.) [ ]
ıer (What?) ______________________

Why? ____

2. Which source of information was the least useful?

Lecture notes [ ]
Lectures [ ]
Guest lectures [ ]
Course literature [ ]
Web library [ ]
Other web sources (company web pages, university web pages etc.) [ ]
ıer (What?) ______________________

Why? ____

3. Which part of the lecture series did you find the most helpful?

a) Introduction to HCI [ ]
b) Application areas in HCI [ ]
c) User-Centred Design [ ]
d) Interaction models [ ]
e) Social organisation and work [ ]
f) Human and computer characteristics [ ]
g) Requirements gathering and definition [ ]
h) Task analysis [ ]
i) User modelling [ ]
j) Design issues, principles, guidelines and standards [ ]
k) Iterative design and prototyping [ ]
l) Design rationale [ ]
m) Usability evaluation [ ]
n) Help and support systems [ ]

Why? ____

4. How did checkpoints influence your work?
5. Did you get enough feedback from the instructor at checkpoints?
6. What was the role of the design workshop in completing the course project?
7. What was the work in groups like?
8. How did you divide labour within your group?
9. In what way did you arrive at decisions in your group?
10. What were the advantages of teamwork, and respectively, the disadvantages?
11. How did you communicate with the other members of your team?
12. If you did the work alone, why?
13. How did the final prototype guide your work?
14. Was there anything particular you learned about the UCD because of the prototype assignment?
15. What was the impact of other groups' prototype presentations to your own design work?
16. Did prototype presentations help you in other ways, for instance, to perform cross-evaluation?
17. Did cross-evaluation improve your own design or the prototype? If so, in what way?
18. Other comments or observations.

Thank you very much for your time!

Appendix 2: SAMPLE RESPONSES FROM STUDENT INTERVIEWS

Table 1. Sample Responses to the Checkpoints

Checkpoints
I thought of the checkpoints as deadlines, and I know that I would not do anything without a strict deadline. To be honest, I'd say that they were extremely good to have in the course. This made me (us) work on the project every now and then, and to keep up the pace. It is one way of motivating the students: It is in our benefit if we get feedback.

Table 3. Sample Responses to Feedback

Feedback
We expected perhaps more. Of course it is nice to have positive feedback, but we would have liked to get more exact comments like what was good about it. Well, sometimes it was a bit scarce but overall, yes. A bit more details on how to proceed would have been preferred. If someone says this should be done better, he should also say which part to improve in what way. Suggestions for improvements are OK. You have a chance to change before the next step. (We got) good feedback. Feedback can be a reward … the teacher recognizes that something important has been done.

Table 2. Sample Responses to Teamwork

Teamwork
We did the work mainly together but when possible we did the writing separately and then discussed resulting texts together. The designing itself was done together. High involvement in the meetings … regular meetings. We used e-mail for coordination, the distribution of assignment materials, to share thoughts. Most work we did face-to-face plus e-mail. In the meetings, we used the drawing board quite much. We used also a digital camera to capture info on the board. I and X worked out the concept. The computer scientist built the prototype. I acted as an interpreter, explaining in Chinese our design suggestions to the computer scientist. Each one of us focused on a different task because we have different expertise, and we had to deliver fast.

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