Rethinking HCI Education for Design:

Problem-Based Learning and Virtual Worlds at an HCI Design Studio

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Abstract

The practice of teaching and learning Human-Computer Interaction (HCI) design has to develop its own approaches that balance method and technology use with reflective and situated practice. We present our HCI design studio course that makes a combined use of constructivist pedagogies and virtual worlds aiming to aid students reflect on the use of related methods and technologies in design and to cultivate more general skills like self-directed learning, intrinsic motivation and critical thinking. Our HCI design studio course can be thought of as an iterative and incremental teaching and learning process that blends HCI methods, design practice and technology between a real and a virtual design studio. The course introduces problem-based learning to the pedagogies of project-based learning and studio-based learning currently employed in most HCI design studios. The positive student responses and our reflection and experiences focusing on a number of challenges for further implementation are also outlined.

Keywords

HCI; design studio; pedagogy; problem-based learning; virtual worlds.

Introduction

Human-Computer Interaction (HCI) education is expanding. Up until a decade ago, HCI was a single course in the curriculum of computer science academic departments and the principal concern of HCI educators was to integrate related theory and methods to software engineering (Faulkner & Culwin, 2000; Manaris, 2003). Now, HCI programs are emerging that are centred on training students to become HCI professionals (Greenberg, 2009). Furthermore, HCI courses are now embedded in a wider set of multidisciplinary curricula in engineering, management and design. The demand for HCI courses in many academic programs will probably increase in the near future since that technology continuously penetrates many human activities; and the large corpus of HCI user-centred methods can be of use to multidisciplinary (e.g. Winograd & Klemmer, 2005) and transdisciplinary (e.g. Nordahl & Serafin, 2008) educational programs.

There is increasing interest in informing HCI education with practices from other learning approaches and methods in science & engineering education, and especially from design learning in studios (or studio-based learning - SBL). In science & engineering education a number of constructivist or inductive pedagogies have been employed with encouraging results (Prince & Felder, 2006), including: Problem-Based Learning (PBL) (e.g. Xiangyun et al, 2010; Chang & Wang 2011), Project-Based Learning (PjBL) (e.g. Capraro & Slough, 2009), and inquiry-based learning (Olson & Loucks-Horsley, 2000; Bernold, 2007). In addition, the instructional design of HCI design studios needs to combine cohesively the large corpus of related theory and methods within the reflection-in-action (Schon, 1985) practice found in design disciplines like architectural and product design studios. Furthermore, making use of technology is imperative for HCI teaching for many reasons including that: students and tutors are already making use of various technologies for their work; there are many technological tools that can mediate HCI design in various phases and stages (e.g. tools for prototyping of the user interface, remote usability evaluation, online survey; card sorting, etc.); the outcome of the HCI design process is a technological artefact of some sort, a software or user interface prototype.

The need for considering new pedagogies in HCI education that creatively synthesise HCI theory and methods, design thinking-in-action and technology has been identified by many (e.g. Lundgren et al, 2006; Faiola, 2007; Kolko, 2010, Blevis, 2010; Cennamo et al 2011). In this respect, Faiola (2007) argues that "*Pedagogical models employed by many HCI and design programs will risk becoming increasingly short-sighted if they do not provide students with knowledge domains that can account for understanding design, social context, and business strategies in addition to computing*." In addition, if we want to develop design-oriented, multidisciplinary HCI courses, to simply adopt the studio approach to HCI teaching will not suffice. In this respect, Blevis (2010) notes that "*Design studio – style learning fosters a number of very desirable qualities, but it also suffers from some perceived limitations: lack of scalability, possible lack of rigor (primarily in the failure to include core concepts and methods of HCI as curricular material), and a perceived lack of structure and specificity for assignments that is outside of the comfort zone of many students (and professors) who are used to the lecture style of teaching.*" Thus, the practice of teaching and learning in HCI design studios has to develop its own approaches that balance method and technology use with reflective and situated design practice.

We present our HCI design studio course that is different from other courses in two dimensions. First, it adds the Problem-Based Learning (PBL) pedagogy

(Barrows, 1986; Wood, 2003; Savery, 2006) to the activities of current HCI design studios with the aim to cultivate student generic skills and attitudes, like: self-directed learning, team working, intrinsic motivation and critical thinking. Second, it proposes the experiential use of Virtual Worlds (VWs) in the form of virtual design studios, i.e. 3D digital places equipped with tools that enable collaborative design to contribute to students' technology design competence. The proposed approach introduces new pedagogical and technological elements in an HCI design studio, thus adding new possibilities for HCI design educators to choose from.

An overview of HCI design studio courses

A considerable number of educators are designing HCI courses in order to connect them to design practice in various ways: (a) some propose design-centred HCI course content and curricula (e.g. Faiola, 2007; Nordahl & Serafin, 2008); (b) others enhance the traditional project-based approach of HCI courses with teaching methods that promote design practice (Harrison et al, 2006; Biskjaer et al 2010); (c) others have developed HCI design studio courses (Reimer & Douglas 2003; Greenberg, 2009; Blevis, 2010; Hundhausen et al, 2010).

The principal pedagogy, i.e. the study of the process of teaching and of strategies or styles of instruction, of learning in design is SBL. Learning in studios has a long tradition in art & design schools and has been studied in depth in the design disciplines – especially in architecture and product design. It involves work in open-ended design domains, a number of structured conversations of critique, and some kind of public presentation of the work throughout the learning process (Shaffer, 2007). The principal strength of the design studio according to Schon (1985) is the 'desk crit': a loosely-structured and extended interaction and collaborative work between the designer (the student) and the expert(s) or critic(s) (the tutor – and/or perhaps other students) during design-in-progress. Learning in studios requires the interchange of creative thinking methods about the design problem and acting by expressing ideas and sketching.

There is a growing corpus of HCI design studio courses that present different approaches on teaching, learning and technology use (**Error! Reference source not found.**).

Table 1: Core concepts of HCI design studios.

Reimer & Douglas (2003) propose teaching HCI with the studio approach by integrating HCI lectures with studio courses. In their course they provide students with a set of projects highlighting design issues that students should focus and they let students work in groups to deliver design solutions. Their approach combines the traditional project-based learning (PjBL) approach to HCI with SBL with the teacher to take up many roles including coaching, providing resources and reviewing student work.

Harrison et al (2006) present a PjBL approach to HCI courses that emphasises the student exploration and self-identification of method use in their projects. Despite there are no studio sessions, the approach takes many assumptions made in SBL and has been applied in three undergraduate and postgraduate courses in the area of HCI and design. The 'it's just a method' method consists of two parts: (a) providing a "tidal wave" of methods of many sorts without commitment to their underlying principles, and (2) to drive reflection following their use. The role of the teacher is that of the reviewer who provides critique in terms of the results of the method. The 'it's just a method' method could be applied in a studio setting allowing critique during design-in-action; this is an orientation that we have followed in our approach.

Greenberg (2009) picks the best practices of design studios, including sketching, desk crits, and portfolios, within a computer science department by mixing lectures with studio sessions. In this course, students are introduced to "*four quite different state-of-the-art interaction domains, each chosen to minimize students' pre-conceived notions of what comprises a 'standard' design within these domains and they are given substantial freedom to design projects within these domains*". Students work in groups and the role of the teacher switches between that of a tutor (when giving lectures) and of the expert (when providing critique).

Blevis (2010) proposes Design Challenge Based Learning (DCBL) with the core idea to present designers with humanity and life-centred issues-based design research and design-concept challenges in the arena of HCI and design. In the DCBL approach design research and concept projects are assigned each week individually. Students deliver sketches of design concepts based on research they carry out on their own. Then students work in large groups to discuss the concept designs and vote for the most compelling ones and then continue to the analytic design and prototype development of the prevailing concepts. The DCBL approach allows for multidisciplinary design education and rests on increased student motivation, self-confidence and creativity. The teacher role is rather detouched and acts more as a facilitator of the whole process.

Hundhausen et al (2010) present the 'prototype walkthrough' as a form of design crit in HCI design studios. In the prototype walkthrough, a group of students presents their low fidelity prototype to the class having one of their members play the role of the user who thinks aloud. Other students can interrupt at any time with questions and comments. Hundhausen et al suggest that prototype walkthroughs create ideal conditions for learning about design. The proposed method is a variation of the pluralistic walkthrough (Bias, 1994) method for the evaluation of user interfaces. The prototype walkthrough can be an interesting activity in an HCI design studio course and might also be employed incrementally from ideation to evaluation. In addition they have developed a software tool for low fidelity prototyping to support the design process.

All these HCI design courses are quite different and present diverse ideas in their conception and process. But, they have one thing in common: they provide a design orientation for HCI education that mixes and adapts the traditional PjBL pedagogy of HCI education with SBL pedagogy of design education. In typical HCI courses lectures are the norm, design is taught in the form of 'examples' and projects are given to students as 'homework'; while in these aforementioned courses design happens in a studio allowing reflection-in-action during interaction with the teacher. On the other hand, the SBL pedagogy is not taken 'as–is' in all the above courses: in all courses students work in groups (this is a major requirement for an HCI design studio in contrast to SBL since that the development of interactive systems is essentially a team process) and in most of them it is required to make use and reflect on HCI methods; also the role of the reviewer passes on to students as well; and last but not least, in these courses technology is an integral element of the process, both a material of design and a tool that mediates design work.

Embedding the problem-based learning pedagogy in the HCI design studio

The constructivist or inductive pedagogies like PBL, PjBL, case-based learning, inquiry-based learning, discovery learning, etc., are relevant for an HCI design studio. Prince & Felder (2006) note in the context of engineering education that "*inductive methods are consistently found to be at least equal to, and in general* *more effective than, traditional deductive methods for achieving a broad range of learning outcomes*." They further identify a set of common characteristics for these pedagogies, namely that they are all: *learner-centred* in the sense that they place more responsibility on students for their own learning; *constructivist*, in the sense that they acknowledge that students create their own view of learning and reality; *collaborative* in the sense that they require from students to work in groups; and they promote *active learning* by requiring that students discuss questions and tackle problems in class.

Currently, HCI education is penetrated by the PjBL pedagogy (Barron et al, 1998; Thomas, 2000; Ayas & Zeniuk, 2001). Project-based learning (PjBL) organizes learning around the notion of projects. According to Thomas (2000) "*projects are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations*". The PjBL tradition is common in schools of management, computer science, and engineering. In PjBL, the teacher can take up many roles during the lifetime of the course like: coach, project member, reviewer, etc., while students work with a high degree of autonomy. In PjBL, it is assumed that the methodology for carrying out the project is given and that students are called for applying known methods with accuracy and professionalism.

PjBL has often been related to PBL (Problem-Based Learning); this is mainly due to the realistic and authentic context for problems/project provided in both approaches. Barron et al (1998) identify 4 principles for designing Project-based and Problem-Based Learning curricula: (a) defining learning-appropriate goals that lead to deep understanding; (b) providing scaffolds such as "embedded teaching," "teaching tools," sets of "contrasting cases," and beginning with problem-based learning activities before initiating projects; (c) ensuring multiple opportunities for formative self-assessment and revision; and (d) developing social structures that promote participation and a sense of agency.

In PBL, students are presented with an authentic problem and context and work in groups and autonomously to identify a route to a solution. PBL should not be confused with problem solving, which involves the derivation of a single correct answer from a well-defined problem, using a formal and rigorous process. On the contrary, in PBL the problem is authentic and related to practice; the process of inquiry needs to be identified by the learner; the outcome is essentially a unique proposal to tackle the problem. According to Wood (2003), students use triggers found in the problem to define their own learning objectives. Then, they do independent, self directed study before returning to the group to discuss and refine their acquired knowledge, thus they take responsibility for their own learning. Savin-Baden (2000) remarks that PBL "*can help students to learn with complexity, to see that there are no straightforward answers to problem scenarios, but that learning and life takes place in contexts, contexts which affect the kinds of solutions that are available and possible*". Nelson (2003) argues that PBL can be employed to restructure computer science courses, programs of study, or entire institutions provided that professors conceptualize "*curriculum as problems, place students in the role of designers, and reconfigure classrooms as design studios*".

In our approach we were concerned with marrying the PjBL and the SBL pedagogies in order to aid students reflect on the use of HCI methods. In addition, we felt that the multidisciplinary nature of HCI and design requires the cultivation of more general student skills like self-directed learning, learning how to learn, intrinsic motivation and critical thinking. Notwithstanding that PjBL and SBL can contribute to the development of these generic skills to some extent, we decided to inject the PBL pedagogy into some of our HCI design studio activities in order to address some of the known shortcomings of these approaches as well. For example, a number of drawbacks have been identified for learning in studios, mainly the stressful process of design criticism for learners and the danger of excessive subjectivity from tutors (Frederickson & Anderton, 1990) – these can be addressed by injecting a PBL approach to studio sessions that requires from (groups of) students to reflect on their designs and try to identify learning issues themselves. In addition, in PjBL it is common that the methods for project development are given – we did not want to do that but let students to make justified decisions on the use of HCI methods and take responsibility for their own learning; this is what they will do in practice after all. In **Table 2**, the main elements of the three aforementioned pedagogies are summarized.

Table 2: Main elements of PBL, PjBL and SBL.

The Studio Course for HCI Design

Course context and goals

The HCI Design Studio course is offered at the MSc program of Design of Interactive and Industrial Products and Systems, at the University of the Aegean, Greece. This is a transformation postgraduate program that accepts candidates from a wide variety of disciplines related to design (e.g. computer science, engineering and architecture) and provides them with the skills that enable them to make creative use of technology, scientific methods and the arts in order to contribute to the design of functional and usable products and services. The HCI design Studio course is offered at the second semester of study, just before students begin their MSc thesis. At that point or in parallel to this, students are attending courses related to HCI theory and methods, informatics, ergonomics and advanced user interfaces.

The goals of the HCI design studio are related to (a) knowledge and skills; (b) the design project; (c) use of technology.

Knowledge and skills: The course aims to cultivate general skills to students: (a) to develop critical thinking through reflecting on their (group) work as well as on the use of methods found in HCI and design literature; (b) to learn to work in groups; (c) to develop intrinsic motivation and responsibility about work and learning; (d) to learn how to learn through the practice of self-directed learning. Students have to make justified use of HCI & design methods in their projects - in this respect they have to try to make use of various methods and reflect on their usefulness for their project.

Design project: A design project has to be developed from ideation to user evaluation that can be added to their portfolio, as well as a design report. The project is authentic and related to practice and requires field research as well as design work. Thus student learning is centred to this design project that neither has a single correct line of inquiry or methodology to be followed nor a unique solution. Students work in collaborative groups to identify what they need to learn in order to solve a problem and come up regularly with presenting their progress to get feedback and critical criticism.

Use of technology: Students have to make selective use of a number of technologies to make project work more effective including: (a) the VW design studio developed for this purpose, (b) a wiki space for communicating texts and documents, (c) other tools like online survey tools, online prototyping tools, usability evaluation tools, card sorting tools, etc (an indicative list is given to students at the start of the course). The role of technology use is significant for HCI design studios because it contributes to digital design competence. According to Arvola & Hartman (2008) in HCI design studios it is important that students gain digital design competence, i.e. "*ability to confidently and critically design digital media for other people's confident and critical use of that media in their fulfillment of certain socially relevant purposes*." In addition, technology can be considered as core material in interaction design studios (e.g. Lundgren et al 2006).

The HCI design studio meetings took place at a computer lab that had extra space for student work in sketching and noting when required. The students' working studio space was next to the computer lab but meetings were not held in that room since that there were not personal computers for all students and teachers available – the use of the web and other technologies was required during the meetings. In addition, students worked in the VW studio, which allowed for extra sessions with teacher participation before the presentations of intermediate results of major project phases.

Design project and phases

The design project given to students was defined as follows.

> *Design a (multi-) touch interactive table or kiosk for a public place like a cafeteria, cinema or theatre. Consider alternative installations, e.g. on top of cafeteria tables or cinema seats, at the entrance, etc; the location of the installation will affect the utility of the installation and goals of the software multimedia application. Type of services of that application may be "business services" like browsing/searching the product catalogue and ordering/booking, and "entertainment services" like*

web browsing, games and communication with others (e.g. other tables in the cafe). The design should take into account "tangible requirements" like table form, table dimensions, etc.; however it should focus on the aspects of the software user interface and user interaction techniques. You should make careful and justified use of design methods to deliver a brief design report that will show off the design models created and an evaluated prototype of the designed artifact using some HCI evaluation method and/or the VW.

The available time for the HCI design studio course was 3 hours every week for 12 weeks; so, this was the time available to deliver the project. We knew that this time would probably not suffice for course meetings, so we held another 4 additional sessions in total in the VW. The course had the following schedule:

Introduction (1 week). The first week of the course was used to explain the approach and technology, and to provide context to the design project for each group. A total of 10 students participated in the course and 2 groups of 5 students with ranging backgrounds were formed by the teachers. For each group a specific context for the project was determined: mainly the specific client for the project who would provide the field for research and potential content. The first team decided to design an information kiosk for the theatre nearby the university, and the second team decided to design a multitouch table for a specific cafeteria, which is a popular student haunt. For both projects stakeholders and potential users could be reached easily. Also, the technologies to be employed in the course were presented with a focus on the VW.

Research & inquiry (~3 weeks). The phase of research and inquiry was set as the first problem that students would have to address. This phase requires use of HCI research and requirements methods. Students were provided with bibliography on the following methods from which they could choose or adapt: interview strategies, observation strategies, contextual inquiry and models of contextual design (Beyer & Hortzblatt, 1998), user segmentation strategies and personas, content inventory tools and methods, competitor analysis strategies (Garrett, 2003), mood boards, designing brand identity, and goal setting methods (Cross, 1998).

Design (conceptual & analytic) (~ 5 weeks). The phase of conceptual and analytic design was set as the second problem that students would have to address. This phase requires the use of HCI and design methods for articulating design concepts and solutions. Students were provided with bibliography on the following: (a) 'design process' methods: brainstorming (Cross, 2008), scenario-based design (Carroll, 1995), interpretation sessions (Beyer & Hortzblatt, 1998); 'design modelling' methods like: visioning (Beyer & Hortzblatt, 1998), concept modelling (Brown, 2007), storyboarding and information architecture methods; and prototyping methods: paper prototyping (Snyder, 2003), wireframes, screen designs and virtual prototyping. They also used free sketching of ideas and they adapted these models according to their requirements.

Evaluation (~ 2 weeks). The phase of evaluation was set as the third problem that students would have to address. Students had to make use of an HCI evaluation from: prototype walkthrough in the VW, paper prototyping (Snyder, 2003), prototyping with online tools, and user testing methods in the case they had devoted time to reach to a fully working demo.

Final presentation and assessment (1 week). The last week of the course was devoted to the final project presentation as well as to course and peer assessment.

The main phases of the project development during the HCI design studio course were considered as problems of HCI and design methods use. In this respect a considerable time of each session was devoted to collaborative work on the identification of areas of further study and the assignment of atomic research and learning tasks for each student by all group members. It needs to be noted that students were free to identify and use other methods than those provided in the selected bibliography, provided that they could find them in their self-directed study and elaborate on their decision during studio meetings in the lab.

Course process and activities

The HCI design studio course process was iterative and incremental, blending HCI methods, design practice and technology. The main activities conducted during the course were: (a) presentation; (b) critique; (c) reflection; and (d) design. Of course, these activities had to be continued by students alone through the week, e.g. design was refined, presentations were prepared; etc. In addition, individual, self - directed learning had to be conducted in the form of research (in the field and/or bibliography) during the week that fed through all stages of the course process. These activities and process are depicted in **Figure 1**.

Figure 1: Outline of the iterative process and activities followed during each HCI studio course work.

The style of presentations differed depending on its scope and purpose. Typically the course started with student presentations that had to be kept short – not more than 20 minutes. Some presentations took much longer however because they were interactive and teachers were allowed to intervene and provide critique and questions. Most of the presentations were held in the VW studio (**Figure 2**) – this was suitable for students to maintain the corpus of presentations in the digital space as well as for teachers to provide questions and critique with digital annotations as well.

Figure 2: Presentation in the Virtual World.

It is important to note that during the critique sessions in the HCI design studio we tried to avoid coaching and correcting students work, but we attempted to provide a set of questions about the fundamentals of HCI and design method use in the context of their project. This is because we wanted to act as facilitators and guide students in the learning process, pushing them to think deeply, and to identify the kinds of questions that students need to be asking themselves, thus forming a cognitive apprenticeship according to Collins et al. (1989). For example, during the first phase of research and inquiry, the first team (information kiosk at theatre) made use of contextual design models for representing requirements, while the second team (multitouch cafeteria table) rest on interviews from potential users and started sketching concepts of the table. We were interested in having students explain why they did these choices making clear that what is important is for them to understand why they followed these methods. It turned out for the first team that the stakeholders of the theatre wanted to put emphasis into ticket booking and selling through the kiosk – and thus an organizational view of the theatre was required and the contextual design approach was preferred. The second team found from interviews that the user experience of “hanging-out” in the cafeteria was the driving design issue of their work, so they felt like experimenting for the very start with sketching and concepts of the user experience of interacting with a multitouch table.

After the presentation and critique which lasted for about 1 hour in each week’s timeframe, the third activity that was taking place during the course time was reflection. This was modeled as a simple PBL tutorial process (Wood, 2003), where students elect a chair and a ‘scribe’ to record the group outcome of the discussion and teachers facilitate the process with posing questions. The aim of this activity for each group was to complete a PBL whiteboard similar to that of Hmelo-Silver (2004) having the following steps:

1. Work on your own for each issue for 5’to identify **Facts** (1st column). Be brief!
2. Present your findings to your team mates. 2’ each. – No critique at this phase.
3. Rework your Facts for 5’ on the basis of your team mates’ presentations.
4. Re-present them to your team mates. – Now discuss them and prepare an agreed, neat list of Facts – 8’
5. Do steps 1-4 for each of Learning issues (2nd column), Ideas (3rd column), Action plan (4rth column).

We note that the time duration listed above proved short during the 1st (research and inquiry) and 3rd (evaluation) phases of the project. These phases required additional planning, and especially at the first sessions, time was running out fast since that students were not acquainted to the process. However, during the conceptual and analytic design (2nd) phase of the project, this PBL table was not used much and changes of models happened in “sketching mode”; it was partly used for documenting comments and corrections made within the team based on teachers’ critique.

The last activity of the HCI design studio course was the collaborative design of the product of the next week’s phase as this was revealed through the action plan. As noted above, the content and time duration of the design activity varied a lot between teams and depended on the phase of the project. The design activity took the form of action planning for the 1st (design and inquiry) and 3rd (evaluation) phase of the project and the form of free-form sketching during the 2nd (conceptual and analytic design) phase of the project. In addition, during the week sketches and models (e.g. personas, concept models, storyboards, wireframes, etc.) were transferred to computer-based models using the VW studio and tools like MS Visio and Photoshop. Furthermore, prototyping and evaluation activities occurred in the VW: one of the two teams opted to create a virtual prototype of the information kiosk for the theatre inside the VW and conducted a usability evaluation with remote users (**Figure**). The other team opted for paper prototyping since that they wanted to focus their evaluation on the gesture-based interaction techniques designed for their multitouch table, so they worked much with paper sketches and compositions.

All in-course activities required atomic research (self-directed learning) that occurred during the week interval. Of course students groups also had a number of extra meetings without us in their studio, and there were a couple of times that we visited them on their request. Furthermore, we held a number of virtual world sessions to discuss various issues usually a couple of days before the final presentations of each phase.

Figure 3: A user approaching the interactive virtual prototype of the info-kiosk.

The virtual HCI design studio: supporting remote collaborative activities

To support the virtual studio activities we have installed a VW in the department's servers and we have developed additional content in the form of constructed places and interactive objects (tools). We used the OpenSimulator platform and MySQL database to set up a standalone VW server and additionally installed the Freeswitch server to provide voice communication support. Students and tutors could log in to the VW using the Hippo browser that was installed in the labs or any other Second Life-compatible browser to connect from their homes. The software we used for our virtual studio in both client- and server-side was open source. Furthermore, we decided to keep our VW standalone, and thus isolated from other regions, and to provide restricted access. Only students and tutors were provided user accounts to log in to the 3D environment and they had to use their real names as avatar names. The reason for these decisions was to be able to better monitor the students' work and progress, e.g. we could easily track the owner of each object that was uploaded in the environment, to record chat sessions of group meetings or class presentations, etc. We decided to use OpenSimulator instead of the most popular Second Life environment, because: (a) we had more freedom to configure the environment, control user access and store the user-generated content for future reference and use; (b) the nature of the HCI design studio requires a lot of images to be uploaded to the VW (e.g. sketches, models, concepts, prototypes) and Second Life charges a price per image upload; (c) most of the features of Second Life are already supported by the OpenSimulator platform.

Before the beginning of the virtual studio we constructed a number of places to be used for student activities. These places are the following:

- **Classroom**. There is one single classroom in a central place in the VW to be utilized for class activities. This room is used during the presentation sessions to let groups display their progress and explain their decisions to the rest of the class. It is designed as a meeting space: it has a display screen on one wall and a large table with chairs around it for students and tutors to occupy. In the entrance there is a space for tutors' announcements about the course and the projects. Furthermore, any notes created by the tutors during class presentations and any drawings on the physical whiteboard of the labs are added as digital content in the classroom space.

- **Private rooms**. Each user has her own private room for which she has exclusive control of the entrance, so she can decide when to allow other users to enter and when to isolate it. The reason for using private spaces is to let students bring their own resources and freely develop their own ideas and concepts before presenting them to the rest of the group.
- **Group collaboration rooms.** There is one room for each of the two groups to be used for collaborative design and learning activities. Initially, it is only equipped with appropriate interactive tools and sample furniture objects (tables, chairs, etc.), and groups are encouraged to design their space according to their own needs and planned activities. The role of these rooms are to support group meetings, to be used as places to collaboratively construct and present sketches and models, to store resources (web pages, papers, etc), to place comments and notes on the project's progress, etc.
- **Prototyping rooms.** Again, there is one room for each of the two groups and its role is to be used for virtual prototyping. The room is initially empty and students are asked, using the appropriate tools to construct a functional prototype of their designed concept and to place it in a realistic context. This prototype is then being evaluated by other users that interact with it as avatars.

Figure 4. Virtual World tools.

We have also developed a number of interactive tools (e.g. Figure 4) using the Linden Scripting Language (LSL) in order to aid students through their activities. The tools were freely available in a specially reserved place in the classroom, and any student can make copies and use them in the world's private or public places.

To support group presentations we have built two special tools, the Projector and the Projector Controller. The first one is used as a display screen with a 'laser pointer' feature (i.e. if one clicks on it a red dot appears in the place) and the second is used to connect to the projector and control a presentation. During group sessions each student can use her own projector controller to upload the presentation images, display them on screen, and move forward or backwards through her presentation.

Group collaboration is supported in multiple ways. Students may use the Annotation object to store notes or comments and place them in the environment. For simpler one or two line notes there also a Short Annotation object that displays the message floating above it, so other users do not have to click on the object and open the note to read it. A collaborative text-only whiteboard is supported through the Message Board object, which can be used for storing ideas, facts or simply group meeting notes. Students can quickly present new concepts to each other using a Sketch Board, through which they can directly draw sketches on a white surface. To create more sophisticated and accurate drawings, they can use the Drawing Board object that displays Google Docs drawings in the VW and lets visitors immediately connect and edit the document. A Post-it Board object is also available as a tool in the VW. Students may add new text messages on it in the form of colored Post-it® notes. Finally, a Chat Recorder object allows students to record chat sessions, play them back, or save them as annotations.

Students also need to store the resources they find during their research to communicate them to others and for later reference. Given that most resources are available on the Web (e.g. scientific papers, information pages, images, e-books, etc), we have added the Resource object for this purpose. It displays a short description of the document it points to, and opens the hyperlink in a new browser window when clicked.

Finally, we have designed and implemented the Interface Element tool to be used for the implementation of the functional user interface prototype. Using multiple copies of this object, students can progressively construct windows containing elements such as buttons and images and define their behavior using simple commands. Currently, interactivity with the UI prototypes is limited to simple mouse clicks. Each working element can have one or more of the following functions: a) operate as a Button, which can send events to other elements (or itself) when clicked, b) operate as a Window, which can contain other elements and it can show or hide based on the event it receives, c) operate as an Image Container, which contains a number of images and it may display the next, previous or any indexed image based on the event it receives.

Table 3: Tools and places of the VW used during project activities

The tools were designed having in mind the specific phases and activities of the HCI studio course.

In research activities, students may use Resource objects to collect and organize documents in their private room and to share them with the rest of the group. They may also discuss about their findings inside the world and store their discussions for later reflection using the Chat Recorder object.

During the design activities, the VW's tools can be used in various ways (e.g. Figure 5). Sketch Boards, Message Boards and Post-it Boards may be utilized either in group meetings or asynchronously in order to record and re-collect ideas and remarks. Graphs, drawings and diagrams that present properties and aspects of proposed concepts can be created either in-world using the Drawing Board object or using an external program (e.g. Photoshop). In the second case they can be uploaded in the VW as images and be attached on existing objects, e.g. boards. Individual members may present their ideas to the rest of the group using a Projector and a Projector Controller object and they can explain parts of the proposed solutions by attaching annotations to them. The Interface Element is being used to construct the interactive prototypes. Comments and suggestions on the proposed solutions can be made by the group members either by posting annotations or using a Chat Recorder during real-time discussions.

Figure 5. Sketches and models of the design project created in the virtual design studio with the use of the sketch board and drawing board tools.

Presentations of group progress to the rest of the class are being made using Projector Controller objects by the presenters that connect to the classroom's Projector. During and after the presentations, the group work is being criticized by the instructors and by the rest of the class using annotations and Message Board objects that contain the comments and suggestions that were made. Furthermore, drawings and sketches made in the physical whiteboard of the lab are being instantly photographed and uploaded to the VW. The concepts and prototypes created by the groups can also be commented by the rest of the class using annotations. Finally a Chat Recorder object may also be used to record a user's reactions and comments whilst evaluating the interactive prototype.

Finally, we have to note that we did not restrict our students to use the tools exclusively for their intended purpose; we rather let them improvise, and in a few cases we were surprised to find that some of the tools had been used successfully in quite unexpected ways.

Student Assessment

The holistic student assessment at an HCI design studio course is a complex issue. This is especially true for the approach followed here, since that we did not want to simply evaluate the quality of the group project outcome but also the process followed by each group and the individual general student skills and attitudes in group work. The assessment of PBL is also an open issue and it is generally dealt with various types of formative and summative assessment tools and methods usually encoded in complex assessment rubrics (O'Grady, 2004).

We articulated a mixed schema for the summative student assessment that consisted of two types of assessment including:

1. Project assessment (60%). This was provided by the teachers of the course on the basis of a weighted set of criteria reflecting the whole process, method use and outcome. The criteria were marked quantitatively and they were followed by individual teachers' explanations for our marks.
2. Assessment of individual student skills and attitudes (40%). This was provided partly by the teachers (10%) and largely (30%) by the students themselves who provided peer and self assessments for their groups. Again, this was based on a set of qualitative criteria adapted from (Yip & Ghafarian, 2000). Only the summary assessment was provided to students, not the detailed rubric.

We need to note that students' response to self and peer assessment was consistent for all students; especially those (one in each team) that were left behind and did not contribute much – they sincerely identified that themselves, as well as their team mates.

Discussion: reflection and experiences

We have presented our approach to the instructional design of an HCI design studio course that adds the PBL pedagogy to the activities of current HCI design studios and makes experiential use of VWs in the form of virtual design studios. The motivation behind this framing was developed due to reasons that stem out of pedagogical goals and concerns, research and exploration, and necessity. We wanted to emphasise an active, PBL approach to learning in this HCI design studio since that this is the last course of a postgraduate program in interactive product design and students should be in a position to take responsibility for their own learning in authentic problems and contexts. In addition we wanted to inform our HCI design course with practices from design learning in studios and since that HCI design studios are not widely-established, we wanted to explore the known benefits of learning in studios in conjunction to PBL approach. Furthermore, we wanted to make experiential use of technologies in this course mainly for allowing students to gain technology design competence, but also to compensate for a–priori limitations in space, time and existing asynchronous learning technologies (Koutsabasis et al, 2001) that could not effectively support the design studio approach; therefore we have developed VW design studio in which students performed many collaborative design activities.

The experiences gained from this course are reported with respect to course results, student responses and assessment, coordination issues and allocated resources. To start with course results, we were very pleased with the process followed throughout the course as well as with the final outcome, i.e. the student projects. The PBL approach enabled students to take responsibility for their own study and follow different routes to their learning and project development. These different routes to research, study and development emerged in-groups and between-groups, and allowed students and groups to contribute with different methods to the course content corpus. This generated opportunities for us to discuss and create awareness about the more generic skills required for multidisciplinary design. In addition, students responses to the course were overall very positive recognizing the novelty and value of the approach, despite that a couple of students complained at first about the ‘lack of guidance’ regarding use of methods and ‘lack of corrections’ on their design proposals; however they got used to that approach especially after they saw their team mates to cope well and deliver interesting results. We also found that this HCI course requires tight coordination and additional time within the course so that all activities are conducted effectively, and between courses – this was addressed in part due to additional sessions in the VW. In addition, the resources to develop and maintain a VW are significant not only in terms of making open source interoperable, but also in creating tools for collaborative design; on the other hand this is a very interesting research dimension that complements with other activities.

The VW has been used successfully during the course in two ways: as a prototyping tool and as a collaboration environment. A notable advantage of the use of the VW compared to the more common approach of letting the group decide about the tools to use lies in the integration and awareness. The group progress was visible to all, so both the tutors and the groups could be aware of the activities that took place and could observe and comment on the documents and solutions that were proposed. This integrated environment allowed remote users to collaboratively construct solutions and communicate in real-time using voice or text chat. In the second case they could also record their discussion for later use. Furthermore, the VW and the tools created for the course offered asynchronous collaboration capabilities that allowed the group to work on their solution in parallel and exchange opinions and ideas through messages, drawings and sketches. Finally, the creative freedom offered by the VW in the sense that students could modify their appearance and construct and decorate their own collaborative space was highly engaging for the majority of them.

On the other hand, there were technical issues faced during the use of the VW that were quite restrictive. The 3D modeling capabilities of the environment were not as sophisticated as in commercial applications and the rendering quality was significantly lower, as expected. This difference caused some frustration to the more experienced students with background from the arts or architecture. Additionally, some students felt that there was extra burden to convert and upload to the VW the documents that they created using familiar applications, such as Powerpoint and Photoshop and they would like to have a less complicated interface between the VW and external applications. Finally, some users found the Interface Element object quite difficult and time-demanding to use, because every single component of each screen should be represented as a different object having its own behavior, and this process could be quite painstaking in the case of more complicated user interfaces.

We are currently applying and refining our approach in a wider range of projects and paths in the multidisciplinary area of HCI, interaction, service and collaborative design (Koutsabasis et al, 2012) involving more students and groups on the basis of the experiences gained. In addition we are working to address several of the issues identified and to set up learning and design problems that will also include customers as users of the environment to allow for more possibilities for collaboration and prototyping. We are also working on the incorporation of specific VW tools for carrying out design activities in the VW like affinity diagrams (taking into account related tools in tabletops, like that of Mohamedally & Zaphiris, 2009), as well as to the formulation of a qualitative approach for the evaluation of HCI design learning activities in VWs with emphasis on issues of assessing critical reflection and intrinsic motivation of students (intrinsic motivation has been identified in other studies like for instance in Shin (2009) but not with respect to PBL and HCI design learning). We expect that in the near future the overall picture of research in HCI design education will emphasize multidisciplinary and constructivist learning combined with the experiential use of purposefully designed technologies to support active student learning.

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