DESIGN EDUCATION VIA WEB-BASED VIRTUAL ENVIRONMENTS

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Abstract The concept of a "virtual" environment has emerged from advances in computer networking, image processing, modeling, simulation and multimedia data representation. During the past few years the concept has been intensively employed in Virtual Design Studios (VDSs) for teaching students both design and Internet technology issues. This paper presents the Web-based VDS as an environment for computer mediated and supported design education. The discussion of the principles, the current state, the advantages and the drawbacks of VDSs is based on our experience in organising four studios. The paper concludes with future trends in the development of VDSs.

Educational Technologies and Design Education

We are witnesses of fundamental changes in the methods and techniques employed to educate and train design students. These changes are the result of an invasion of computer mediated information technologies which meet the evolving needs of our increasingly technological society.

The developments in communications, computing and information delivery services decrease the gap between the conventional and distance learning methods. Both methods include two major components: (i) *course materials* to be delivered to the students; and (ii) *communication* between students and instructors. Lecturers create multimedia course content and post it on the Internet where it is accessible, for instance, via the World Wide Web (WWW). Students communicate with instructors via e-mail or through a video conference session. These techniques are referred as *computer mediated and supported instruction* (CMSI) and are being integrated both in basic and distance educational methodology.

Russell (1996) has analysed more than 200 works, published between 1928 and 1996, related to both the university classroom and distance education. The results show that generally there are *no significant differences* in achievement between: (i) students in traditional classes and students in distance-delivered classes; and (ii) distance students at remote sites and distance students within organisational sites where the instructor is present. These results support the development of *unified CMSI methods* for both types of education. The research done by Verduin and Clark (1991) supports this idea and specifies some criteria when unified methods will work effectively. Comparing distance education to traditional face-to-face instruction, they indicate that teaching and

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studying at a distance can be as effective as traditional instruction when: (i) the *method and technologies* used are appropriate to the instructional tasks, (ii) there is student-to-student *interaction,* (iii) there is timely teacher-to-student *feedback.*

Design, as an educational subject, is characterised by the lack of clear separation between theoretical knowledge and practical skills. This is the reason why, from a didactical point of view, the *design studio,* combined with easy accessible information sources, has proven to be the optimal learning environment for architectural design students. The instructional strategy in the design studios is based on constructivist principles in which a student actively constructs an internal representation of knowledge by interacting with the material to be learned. The model implements the principles of situated cognition (Streibel, 1991) and problem-based learning (Savery and Duffy, 1995). According to these theories, both social and physical interaction enter into the definition of a problem and the construction of its solution. Neither the information to be learned, nor its symbolic description, is specified outside the process of inquiry and the conclusions that emerge from that process.

On the other hand, present-day architectural design and construction tasks require team work in which there is some collaboration and some division of labour among the members. Thus, teaching *collaboration* becomes an essential part of design education.

Recent developments in computer mediated information communication have extended, to varying degrees, the use of multimedia information sharing technologies in professional design practice. However, these *technologies* are not typically used in teaching design. The introduction of the Web-based virtual environments in the current design education promise to bridge this gap.

Web-based Virtual Design Studios as a collaborative learning environment

The Virtual Design Studio (VDS) combines the didactic model of the traditional design studio with distributed information organisation and communication, creating a collaborative learning environment. Essentially, this is a *networked* design studio, distributed across space and time (Maher *et al.*, 1996a), where

- the team is composed of participants, dispersed in *various locations,*
- the design process and communications between designers are *computer-mediated* and *computer-supported,*
- the information "inside" the studio is handled in *electronic form,*
- the final design *documentation* is also in electronic form.

Thus in the *globally* networked VDS, students are able to participate in the design process from the office or home, or from any city with network interconnectivity. The *workspace* of the studio is distributed across the net. We use the term “global” to stress the difference between the idea behind the VDS and the conventional studio equipped with computers, even if they are locally connected.

Mitchell and McCullough (1995, pp.441-462) presented the general idea of the VDS as an extension of conventional studios, discussing different enabling technologies and corresponding studio scenarios.

We have developed and applied the concept of a *Web-based VDS* as an environment for teaching students about *collaborative design.* A traditional design studio occupies a *monolithic physical space* in which designers create their product. As a

learning environment, it is close to a combination of the university classroom and the laboratory, which defines the way students developed their projects. The modification of the workspace in the VDS and the replacement of the physical space by computer mediated educational environment *enhances the studio-styled learning under geographical and time scheduling constraints*.

We present the instructional model of the *Web-based* VDS as a comparison to the traditional design studio in terms of: project definition; representation, documentation and communication of design information; and studio management.

Project definition

In architectural design studios, students normally learn about design as an individual activity, where each student works on his or her own design project. Partly, this practice is due to the convenience of grading individual projects rather than estimating the participation of each student in a collaborative project. In some cases, students are grouped into project teams in an attempt to introduce collaboration.

Defining a design brief in a VDS needs a consideration of the nature of the *collaboration* among the students. To provide some guidelines for the definition of the brief, we identify two extreme approaches to sharing design tasks during collaboration: *single task* collaboration and *multiple task* collaboration.

In single task collaboration, the resultant design is a product of a continued attempt to construct and maintain a shared concept of the design task. In other words, each student has his or her own view over the whole design problem and the shared concept is developed by the "superposition" of the views of all participants.

In multiple task collaboration, the design problem is divided among students in a way in which each person is responsible for a particular portion of the design. Thus, a multiple task collaborative design does not necessarily require the creation of a single shared design concept, though learners work cooperatively in a common electronic workspace.

Single task and multiple task collaborative design are two extreme cases. In a simple design project it is most likely to have the single task extreme. In complex design projects, there are times when the extremes are applicable and times when there is a combination of both types. The last case is most likely to occur in a large-scale tasks.

Represention, documention and communication of design information

In the traditional studio, collaborative activities are based on *face-to-face communication*, work on *drawing boards* and/or *CAD systems*, and building of *physical models*. Documentation is maintained both in paper and electronic form. To minimise communication costs and difficulties, specialised resources, such as drawing archives and technical reference libraries that keep past design experiences, have to be located either in or near the studio. At present there is no adequate knowledge representation model which can become the basis of an integrated representation of design information.

In current Web-based VDSs the electronic common workspace is based on a heterogeneous environment where distributed designers use digital image processing, CAD drawings, and hypertext. We identify two extremes in the management of such amalgamated design information: *formal models* and *informal hypermedia.*

Formal models are typically defined in order to facilitate automation of aspects of the design process, such as transfer from one CAD system to another or automatic constraint checking. Formal models of design products are still a research topic.

Informal hypermedia is a more recent approach to sharing a representation of a design. The information is represented as text, tables, images, 3D models, animated images, and links to other information.

The *structured hypermedia* representation is an attempt to compromise both extremes. The idea is to introduce a regular structure for holding the information chunks and establishing some predefined relationships between the instances of this structure.

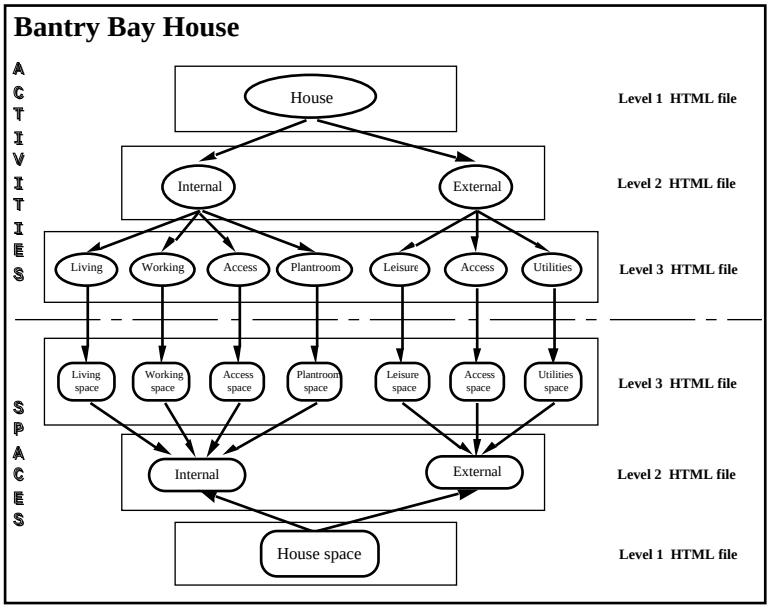

Figure 1. A Web-based realisation of the Activity/Space model

Our current approach to representation in the Web-based VDS put into action the idea of structured hypermedia. The *Web-based Design Document* (Maher *et al*, 1996a) is based on the Activity-Space design information model (Maher *et al.*, 1996b). The idea is illustrated in Figure 1. The initial brief is specified as a set of activities with requirements for minimum space, needs, and owner preference. At each level the description of the corresponding set is stored in an HTML[2] file. These descriptions compose a set of active linked tables that formalises the organisation of the brief. The links follow the decomposition of activities into particular subactivities. In addition to each activity, a link is attached to the corresponding space which has to be designed and documented by the students. The top page of the document includes a navigation tree. Each page of the document has information about current and upper levels, and an "emergency" link to the navigation tree, in case the examiner is lost. An example document can be found at http://www.arch.usyd.edu.au/vds96/elective/brief.html.

Another issue in the information organisation in the educational Web-based VDS is the *document handling*. This matter is closely connected with collaboration type and representation issues. Single task collaboration imposes critical requirements on

[2]HTML - Hyper Text Markup Language

concurrent access, document integrity and security. The issues in the case of multiple task collaboration are related to consistency across the different documents. This approach does make the security issue easier to solve since the participants involved in one aspect of the project will store and maintain only their own documentation.

When considering how computer environment can support the communication of design ideas and information in collaborative work between students, two modes can be identified: *asynchronous* and *synchronous*.

In the asynchronous mode, designers may work at different times, often on different parts of the design and do not require the simultaneous "net presence" of all team members. This mode does not impose critical bandwidth requirements on the network. It also has lower requirements towards designer communication and operation skills. Therefore this is a typical way of joint student design activity during the first few weeks.

The synchronous mode implies the simultaneous "net presence" and participation of all students involved in the collaboration. In this case the interactive design activity occurs in relation to a shared representation of the design that ideally incorporates designers' goals, descriptions, reasoning paths in their design steps, partial solutions to the design task, design communications, and information exchange. Currently, this mode of communication is limited by the need for high bandwidth networks and compatible platform independent video conferencing software and/or specialised groupware at each of the nodes of the distributed studio.

A variety of combinations, labelled as a *hybrid* communication mode, was born in an attempt to exploit the advantages of synchronous communications within the limits of network bandwidth. Basically, in these hybrid modes, students use a text-based chat service for synchronising the simultaneous access to the same multimedia resource (a Web page, for instance) and for discussing and changing the contents of this resource. Table 1 displays examples of network tools used in each mode regarding communicated information.

Information type	**Information communication mode**		
	synchronous	*asynchronous*	*hybrid*
text	Text-based chat service	email, Web-based email "bulletin board"	chat service combined with parallel e-mail exchange
images and models	shared whiteboard, groupware	multimedia e-mail, FTP	chat service combined with synchronised viewing of a same web pages
audio and video	conferencing, groupware	multimedia email, transfer of audio/video file	chat service combined with file playback

Table 1. Design information communication

Studio management

To model the organisation of the VDS, we borrow the concepts of *role theory*, based on the dramaturgical metaphor of a *role* (Wiggins, Wiggins and Zanden, 1994). The management and interactions "inside" the studio are described in terms of *agents* or *actors*, who have particular responsibilities and duties in accordance with a specific

"position" in the VDS. In a traditional design studio, the participants include studio instructors, students, and possibly a client. The current VDS role system includes:

- *client*, who is either an individual person or an organisation outside of the university,
- *teachers and tutors*, who provide the necessary learning materials and tutorials,
- *coordinator*, who manages the studio and controls the results in each stage,
- *student designers*, who are working either on a common or on an individual project,
- *computer system manager*, who is responsible for the functioning of the environment and resolving occurring technical problems.

In practice, actors may overlap or change roles. The tutor and the coordinator are sharing most of the managing activities. The client is responsible for assisting the brief formalisation and refinement. The client and the coordinator are assigning the grades for the final projects.

Web-based Virtual Design Studio in design education practice

Currently there exist several Web-based virtual design studios around the world (Maher *et al*, 1996a). In this section we consider observations from four studios—two in 1995 and two in 1996—whose main site resides in the University of Sydney.

Each of the two 1995 studios—international and Australian—was a "studio of studios", joining several universities in different countries and in different states. The design briefs focussed on two different approaches to collaboration. For the international studio, the design brief focussed on a common design problem but different design sites. The students started their projects in different weeks, due to the mismatch of semester dates. In addition, they were physically present in the studio at different times of day because of the different time zones. This follows the extreme case of multiple task approach to mainly asynchronous collaboration.

The design brief of the Australian studio was common for all participating universities, i.e. the client, the design problem and the site were the same. Students collaborated through the development of several alternative designs for the same site, and finally produced one design. Thus they were involved in both synchronous and asynchronous collaboration. The asynchronous collaboration occurred through shared information on the WWW and shared data files. The synchronous collaboration was supported through video conferencing sessions. As the students progressed through the design, they needed to read and write to each others' drawing files and to develop the final concept as a group decision. This project is an example of a multiple task approach for the first part of the studio, followed by single task collaboration for the second part.

In both studios, the representation and communication of ideas was comprised primarily of visual information. Images were used to illustrate the precedent designs that the students thought were relevant to understanding their design, as well as images of their own designs. The design development was represented as CAD drawings. Those students who used text to augment their images were able to communicate their ideas and intent associated with their design, whereas students who used images only relied on the viewers' interpretation of the design. To promote interpersonal communication, the VDS provided a hypermail bulletin board to allow messages to be delivered to an

electronic mailbox which was archived centrally and available on the Web. During the video conferencing sessions the students imported their design proposals (design images, text, CAD drawings) into the shared whiteboard and then they discussed and modified them.

The design documentation included brief analysis and design solutions in accordance with the informal hypermedia model. The students described their designs through images and paragraphs of text. Visual presentation and document organisation were unique to each student, which caused some problems during grading of the assignment. The results confirmed the paradox within design learning that there are as many correct solutions to a particular design task as the number of designers who are trying to resolve the task.

The 1996 studios were small-scale studios, joining participants from within the same university. The environment organisation was improved and enriched with related tutorials. Accent was placed on the development of the design brief for the students, using the structured hypermedia approach in a way that the brief information is directly related to the resulting designs. Students had to refine the brief and complete the design document filling the spaces left in the structure of the brief.

Several problems were encountered when running these studios. The students enter the studio with different levels of computer knowledge, communication and organisational skills. These factors disturbed collaborative activities during the first few weeks. The schedule of a VDS, therefore, needs to include a *"warming-up"* period. Students have difficulties *adapting* to the reduction of personal physical interaction. The hypermail "bulletin board" does not solve the problem of losing face-to-face behavioural, gestural and tonal cues. This problem was amplified by the unreliability of the video conferencing software.

Strong sides and drawbacks of the educational Web-based Studio

The experience of running four VDSs displayed some didactic benefits for students. The environment stimulates active, creative and explorative learning. Even the creation of the project documentation on the Web is a design problem.

Traditionally isolated distance-education students are brought into the community of peers. They are able take part in several educational design projects with multiple universities and companies, and to participate in an international cross-cultural collaboration.

Students learn electronic communication, collaboration techniques, and etiquette in addition to design technology. They also get experience in creating and handling electronic design documents, and examining potential uses of advanced information processing technologies.

The advantages of the Web-based VDS as an environment include:

- open design towards increasing the functionality of the environment;
- open design towards the incorporation of additional media types either in plug-in or helper format, which enhances the expressiveness of design information representation.
- on-line archiving of design information and keeping track of past experiences to be accessible for other Web-based studios.

The drawbacks of the current Web-based VDS are related mostly to the Web and the client-server models. The Web is not truly interactive, it processes information in a batch mode. This makes the implementation of genuine, immediate and meaningful feedback problematic.

Current studio configurations do not keep track of student access, nor of how far the project has been developed. The counters included on every page of the 1996 VDS do not provide adequate estimate of the access as they include errors of random access, repeated access without purpose, and so forth.

Future trends

The Web-based VDS is most likely to evolve in the following directions:

1. Extending the type and effectiveness of Web utilities for increasing the functionality of the environment. However, these additional utilities have the potential to reduce the integrity of the environment and compatibility with other browsers.

2. Including additional design supporting systems (for example, a Web-based design case library for exploring design alternatives) that use the browser for interaction.

3. Introducing a sense of "place" in the virtual design studio. In current VDS, there is a collection of disjoint physical places that exacerbates the students' need to work together. A sense of place can be developed by defining a virtual place that belongs to all the participants in the studio. We are trialing the idea of a Web-aware MUVE (Multi-User Virtual Environment). We are using the technology of the lambdaMOO language for communication, navigation, and spatial representations with web-aware objects. This environment allows us to design a set of rooms as the studio in which students can meet, work, and present their work. Being web-aware, the virtual space can be visualised by automatic web page generation using the current state of the studio definition. In addition to providing a place for the studio, this environment promotes both collaboration, through its rich language for communication, and constructionism, by allowing students to add to the environment.

4. The current paradigm of the Web-based VDS is relatively static. In order to achieve more effective interactivity, parts of the studio pages related to tutorials and on-line educational materials have to be generated dynamically according to the requirements specified by the student.

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