KNOWLEDGE ACQUISITION IN DISTANCE EDUCATION

Manolya Kavakli, Jason Thorne

ABSTRACT
This paper describes knowledge structuring as a learning strategy in design education. Given that education is the knowledge transfer from one intelligent system to another, we discuss two main characteristics of education: knowledge acquisition and knowledge structuring. In this paper we apply knowledge acquisition methods used by knowledge engineers as an active learning strategy in computer supported design education[1]. Students as the users of the Internet (large knowledge base) should be introduced to knowledge acquisition and knowledge structuring methods as well as search engines. In current educational strategies students are often treated as passive recipients of knowledge. In higher education, students should be provided with the ability to extract the acquired knowledge from distributed knowledge sources as well as from their teachers. We also investigate the nature of computer based learning in a virtual design studio and suggest a model to improve the learning experience. We gain data from a virtual design studio established between Istanbul Technical University and the University of Sydney, where students in teams with their distant partners designed the Sydney 2000 Olympic village by using ActiveWorlds[2]. In the analysis of this virtual design studio, we discuss five hypotheses related to using Knowledge Acquisition as an active learning strategy to improve the process of computer based learning. We use the analogy of developing an expert system in the way of explanation. In this analogy, students are analogous to Knowledge Engineers, designers to Knowledge Based Systems, teachers to domain experts and the learning process to the Knowledge Acquisition process. We conclude by indicating advantages in using Knowledge Engineering methods in the acquisition of design knowledge to build a knowledge base.

KEYWORDS
Knowledge acquisition, distance education, learning strategies, virtual design studios.

INTRODUCTION

The purpose of current educational strategies is to prepare students for professional practice. In this paper, our objective is to discuss the advantages of teaching knowledge engineering and structuring strategies to students. This activity is to acquire knowledge and skills from experts in design education and to restructure themselves. Structuring cognitive activities is important in the performance of tasks. The major difference between experts and novices is in their performance in professional practice. This could be attributed to the differences in their cognitive activities (Adelson, 1985). Certain types of cognitive actions coexist in the execution of mental tasks (Kosslyn, 1984, Suwa et al 1999, Kavakli & Gero, 2001a).

Kavakli and Gero (2001b) found clues for structural organization and systematic expansion in the expert's cognitive activity that could be the reason for the expert's higher performance in the design process. In their

[1] *The term "computer supported design education" refers to both computer aided design process based on the practice in contemporary design studios and collaborative design process in virtual design studios.*
[2] *ActiveWorlds is a virtual reality software environment used for collaborative design.*

case studies, the expert's performance is 2.5 times as much as the novice's, while the novice has been processing 2.5 times as many concurrent actions than the expert. Their experimental findings indicate that the expert's concurrent cognitive actions range from 5 to 7, whereas the novice's concurrent actions range from 7 to 16 which is beyond the limit of a human short term memory (7 +or- 2) as defined by Miller (1956). In the novice's protocol, cognitive performance has been widely distributed, but the expert seems to have the control of his cognitive activity and govern his performance in a more efficient way than the novice, because his cognitive actions are well organized and structured. Thus, the novice's lower performance could be attributed to the unstructuredness in his cognitive activity. This unstructuredness in cognitive activity may accidentally lead to higher rates of certain types of discoveries by making remote associations available because of the novice's defocused attention. In this case, we can also talk about the positive affect of unstructuredness on discoveries, while it may also be the cause for the drop in the performance. Thus, the structuredness in cognitive activity may govern the performance in design process, while the unstructuredness may support the occurrence of certain type of discoveries, making remote associations accessible.

The acceptance of a novices' success in creating novelties and experts' success in using their expertise has implications on design education and raises a question: How can we use structuredness and unstructuredness of cognitive activity to integrate a novice's novelties into expert's expertise? We suggest to use knowledge structuring as an aid to structure cognitive processes of novices in design education. The flexibility of using different modes of structuredness and unstructuredness may be achieved by using knowledge structuring as a self-learning strategy.

KNOWLEDGE STRUCTURING AS A LEARNING STRATEGY

Education is the system of training and instruction that is designed to give knowledge and develop skills. The goal of education is to enable students to cope with the challenges of professional life as individuals and as members of the society. We live in a knowledge society (Drucker 1993). In a knowledge society, knowledge is dynamic and rapidly goes out of date. As defined by Cropley (1999), "The knowledge and skills needed in the future may not even be known at the time a person attends school. As a result, the school cannot limit itself to the transmission of set contents and techniques, but must promote flexibility, openness, the ability to adapt the known or to see new ways of doing things, interest in the new, and courage in the face of the unexpected. These are central elements of a psychological definition of creativity. Such properties help the individual cope with the challenges of life, especially in the areas of change, uncertainty, and adaptation, and they are closely connected with mental health.". How can we achieve this? By giving a personal trainer to every person that graduates from university? Our answer is simple: bringing a person to a desired standard of efficiency can be done not only by instruction and practice, but also by undergoing such a process. The trainee can be his/her own personal trainer as well. Life in a knowledge society requires concurrent teaching and learning strategies such as learning-by-self.

What are the conditions of learning? As put by Glanville (1996), "in order to learn, the learner must not already know. Apart from the obvious condition of ignorance, the learner not only does not know, but knows that he does not know; then he can do something about it, including gaining the motivation to learn." Then, to keep the learner's motivation at its peak, knowledge should not be given directly to the students, instead they should be informed about the topics that they do not know and taught how to reach the knowledge bases in distributed information sources.

In a knowledge society, university education, is considered more of a knowledge industry that aims at transferring both knowledge and skills to students. We attempt to describe education as the knowledge transfer from an intelligent system into another system. From this point of view, both education and AI (Artificial Intelligence) intersect at the context of Knowledge Transfer demand. There are three components of an education system (Fig.1): Transmitter, Receiver, and Hardware system. While Transmitter is in charge of teaching and Receiver of learning, Knowledge is transferred through Hardware & Software.

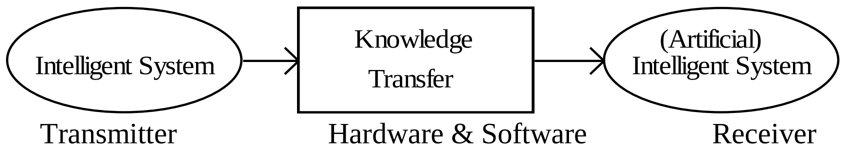

Figure1. Educational system

In the current education system, the success of teachers at reliably passing down the design knowledge depends largely on their pedagogic talents as well as their motivation. Teachers therefore control the flow of knowledge as active transmitter of the education process. Students, however, take the passive role as the recipient of knowledge, even though their education inevitably affects their professional lives. We need to balance the roles of transmitter and receiver by giving the receiver authority to control the amount and quality of the knowledge transferred. This means that students in demand of knowledge should become more active recipients of knowledge. At this point, we turn to knowledge engineers to actively acquire knowledge in a knowledge acquisition process.

Education and AI intersect in the area of Knowledge Transfer. In AI, this is achieved by knowledge acquisition and knowledge structuring. Since the 1950s, AI scientists have been working to find an answer to the question of the English logician A.M. Turing, "Can machines think?" This question, stemmed from the 17th century with Pascal and Leibnitz. It is the wish to make computers "think" that motivated the research in AI applications since the 1960s, but the original question remains unanswered.

The complexity of the human mental processes directed AI researchers to concentrate on narrower fields that are still the focus of the current work. The first Expert Systems appeared in 1970s. Expert Systems attempt to emulate relatively simple areas of the experts' reasoning. In spite of all the restrictions, Expert Systems are still regarded as one of the most important paradigms for solving complex tasks in design process, because they are successful in knowledge structuring "...where the knowledge is encoded into computer as declarations in the form of clauses, rules, objects or frames" (Wiig 1990).

The success of Expert Systems stems from the knowledge acquisition and knowledge structuring strategies used by knowledge engineers. Considering the parallelism in Knowledge Transfer between AI and Education, we may investigate the possibility of using the knowledge engineering strategies for knowledge acquisition and knowledge structuring as an educational strategy. We shall explain our proposal in a series of hypotheses by using an analogy and showing the parallels between Expert System Development and Design Education which aims at growing experts specialized in design discipline.

HYPOTHESES

Hypothesis I: Education => Knowledge Acquisition Process.
Knowledge Acquisition is an approach developed for building Knowledge Based Systems in various fields. As explained by Hayes-Roth *et al.* (1986), the traditional meaning of knowledge acquisition is "incremental addition of knowledge to an intelligent system." Knowledge Acquisition is a process that involves eliciting, analyzing, and interpreting the knowledge used by a human expert when solving a particular problem and transforming knowledge into a suitable (machine) representation. With these contents, Knowledge Acquisition (Fig.2) has similar characteristics to the design education.

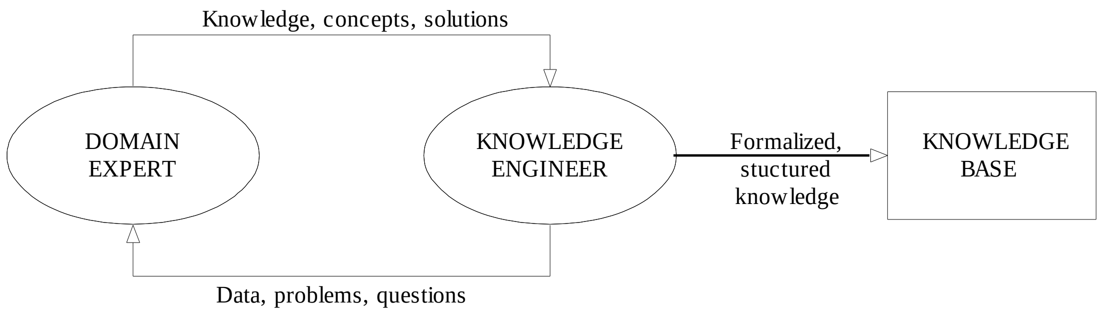

Figure 2.Knowledge Acquisition Process (Waterman 1986)

In a Knowledge Acquisition process, as in design education, the knowledge engineer defines a set of problems and interviews the domain expert on how to solve them. The domain expert explains concepts, solutions, and knowledge in interviews. Knowledge is then formalized and structured by the Knowledge Engineer to construct a knowledge base of a Knowledge Based System. The domain expert then extends and tests the Knowledge Based System, which can be further refined by the knowledge engineer in drawing upon other knowledge sources. This is an evolving process. A Knowledge Based System is never really complete and is built incrementally. We suppose the same would be the case of design education, beyond formal education.

Knowledge Acquisition is an empirical approach developed by the methods of Cognitive Science. The difference between the knowledge representation model and the mental model of an expert is decisive for the quality of the knowledge acquisition and consequently for the Knowledge Based System itself. This is also a representative of the quality of design education. Knowledge Acquisition (Fig.3) can be accepted as an empirical investigation tool for design research, in the exploration of design methods of experts (designers).

Adopting the descriptions from the Knowledge Acquisition process, we investigate the corresponding roles of Transmitter and Receiver that we initially defined as the components of an education system. Transmitter corresponds to the expert and Receiver to the Knowledge Engineer. On the basis of this assumption, we can presuppose that education is equal to the Knowledge Acquisition process in a Knowledge Based System development. In this analogy, we consider teachers to be the domain experts or Expert Systems, designers to be Knowledge Based Systems, and students to be Knowledge Engineers. We prove our hypothesis, illustrating the similarity of these roles in the following parts:

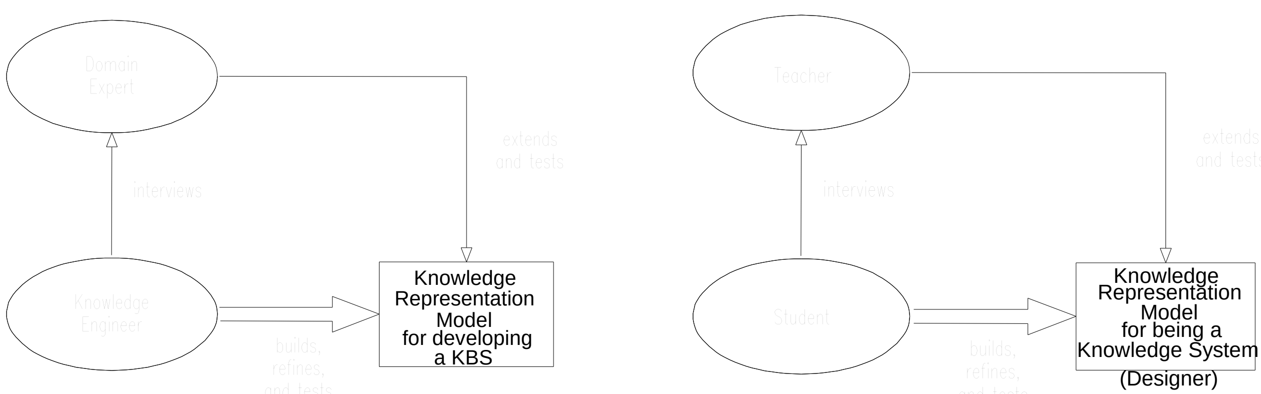

Figure3. The roles in Knowledge Acquisition for AI and HI

Hypothesis II: Expert Systems => Teachers

The distinctive property of Expert Systems is to lead to knowledge processing, instead of data processing. The claim of Expert Systems is to provide with a new language and a new methodology for automating knowledge-intensive processes. Thus it opens a door to a new stage of information technology development. Unlike human experts, Expert Systems are claimed to be the first information processing systems being able to explain their line of reasoning (Schefe 1988). Expert Systems achieve this by encoding factual & heuristic knowledge as well as reasoning methods in a computer program in a structured form. The overall goal of Expert Systems is the reproduction of human expertise on a computer program. This reproduction is executed by means of inferences from a knowledge base. We believe that if human experts (teachers in our hypothesis) could explain their line of reasoning in a similar way to the Expert Systems, they would play a more active role in knowledge transfer in design education. This requires them to have systemic knowledge of the domain. This means they have to be Knowledge Based Systems, before they become Expert Systems.

Hypothesis III: Knowledge Based Systems => Designers

Knowledge Based Systems is used by some as a synonym for Expert Systems and others as a term of classification. The term Expert Systems is generally reserved for systems that truly rival human experts and the term Knowledge Based System is used when speaking of small systems developed by means of AI techniques. Hillenkamp (1989) characterizes content and context of Expert Systems as "Knowledge Based Systems for knowledge workers in a knowledge-oriented industry." Regarding teachers as Expert Systems and designers as Knowledge Based Systems, we can refer to this definition (Fig.4): "Teachers are the designers for students in a university." Some Knowledge Based Systems are implemented as Expert Systems as some designers are regarded as experts.

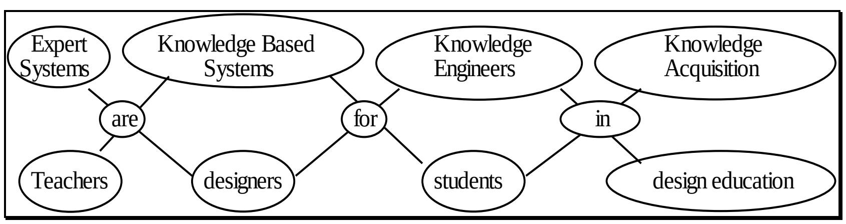

Figure 4. Similarity between Knowledge Acquisition and Learning Process

Hypothesis IV: Design Knowledge => Expertise

Expertise is the knowledge that is acquired over many years of experience (Rosenman *et al.* 1987). It is reasonable to suppose, therefore, that experts are the ones to ask when knowledge engineers wish to represent the expertise that makes their behavior possible. Because experts are able to provide an answer to particular types of questions (Kornwachs & Bullinger 1989), and -because of training and experience- are able to do things others cannot (Johnson 1983).

If we assume a designer is a KBS, its knowledge refers to the knowledge of the designer. As a design progresses, designers not only increase their store of information in the form of facts, but also appear to change the way information is organized. When a system learns, it undergoes *structural change*. The system itself is seen as dynamic. Learning may also bring about changes in the control of a system. "The acquisition of any kind of information may be seen as a form of learning. There are two major sources for design knowledge. A system can learn from its own activities and also from the activities of other systems. The body of existing designs constitutes the knowledge base, and we reason with these designs anologically" (Coyne et al. 1990).

Hypothesis V: Knowledge Engineers => Students

A Knowledge Engineer is the person who designs and builds the Knowledge Based Systems (Waterman 1986). A Knowledge Engineer extracts domain knowledge from the human experts (their procedures, strategies, and rules of thumb for problem solving), and builds this knowledge into the Knowledge Based System. A knowledge engineer who is in charge of organizing knowledge for his knowledge base must be able to handle formal tools like (programming) languages (in AI), as well as to have a satisfying understanding of the field the knowledge comes from. Moreover he must be able to be a serious and competent dialogue partner for the experts and he must be able to translate from one specific area language into another. He must keep in touch with all participants of this process and he is in charge to perform the management for the knowledge acquisition phase. With these characteristics, the role of a Knowledge Engineer is similar to a design student (Fig.5).

According to Wiig (1990), "In Expert Systems, the domain knowledge and reasoning strategies of one or several experts are captured through knowledge elicitation and modeling by Knowledge Engineers and then automated as a Knowledge Based System to support either the experts themselves or other knowledge workers." In design practice, this expertise may be captured through knowledge acquisition methods applied by the design students. Students who work for gaining the expertise of their teachers can be regarded as knowledge workers.

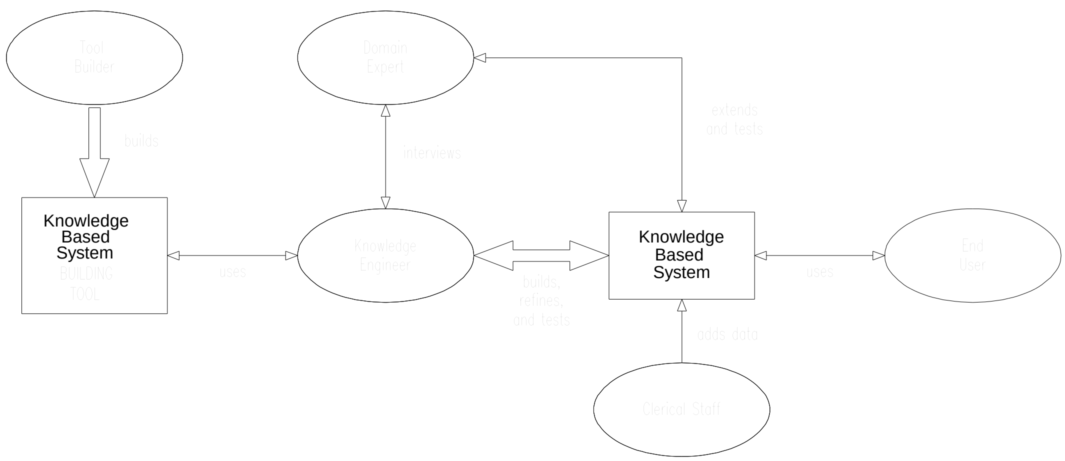

Figure 5. Role of Knowledge Engineer (Waterman 1986)

Thus, the teacher provides guidance to students in their strategies of eliciting the knowledge which is most beneficial to them, placing them in the active role of the knowledge transfer. In this way, students become knowledge engineers, building knowledge bases corresponding to their own capacity, background, demands, and style. This might be a contemporary version of the well-known educational strategy "learning-by-self".

A MODEL FOR COMPUTER BASED LEARNING IN A VIRTUAL DESIGN STUDIO

As a model for knowledge acquisition in design education, we turn to the wealth of experience made in knowledge engineering. "The process of building a Knowledge Based System is often called Knowledge Engineering. Knowledge Engineering typically involves a special form of interaction between the knowledge engineer and one or more human experts in some problem area. "The professional activities of a knowledge engineer are associated with eliciting (or acquiring), codifying and encoding knowledge, conceptualizing and implementing Knowledge Based Systems, and engaging in activities to formalize knowledge and its use, particularly through application of AI" (Wiig 1990). The methods developed in Knowledge Based System technology can act as a model for the design education process.

Knowledge Engineering employs a technique to elicit data (usually verbal) from the expert and helps to interpret these verbal data in order to infer what might be the expert's underlying knowledge and reasoning process. For building a Knowledge Based System, domain knowledge and reasoning strategies of experts are captured and automated by Knowledge Engineers through Knowledge Acquisition and Knowledge Modelling. In Knowledge Engineering as a learning strategy, students -like Knowledge Engineers- try to capture and replicate the domain knowledge and reasoning strategies of their teachers. This is in contrast to the current educational strategies where the knowledge is directly transferred to the students. Following the big hidden arrows in Figure 8, we propose to change the direction in education, and have the students take the active role in Knowledge Acquisition and Knowledge Modelling for building *themselves* as Knowledge Based Systems (designers). There are a number of knowledge acquisition approaches used to reach the knowledge sources in Figure 6. Public knowledge may in part be acquired from textbooks, articles or other sources in the public domain through reading or even copying of databases. Expert knowledge and private knowledge however, require sophisticated elicitation methods.

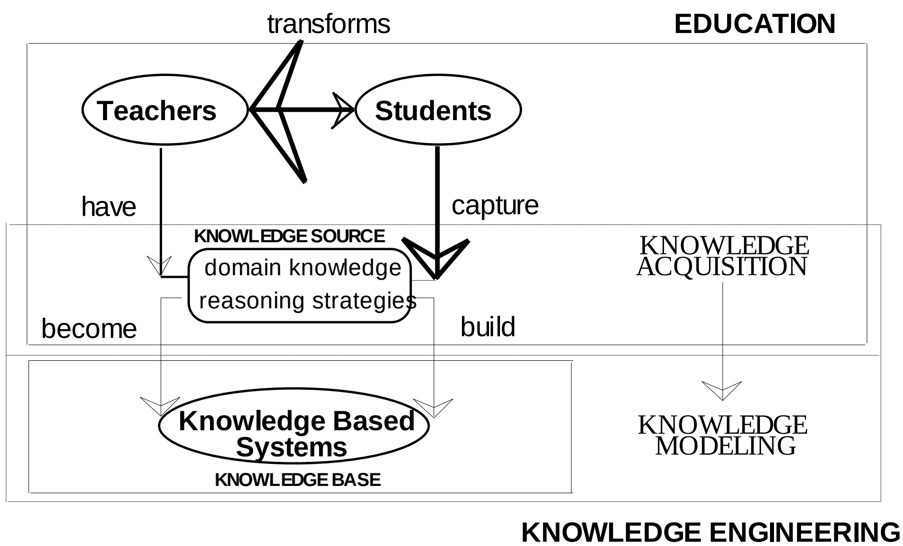

Figure 6. Knowledge Engineering as a Strategy for Design Education

The following direct elicitation methods (Wiig, 1990) may be used in design education:

- Interviews: These are categorized such as; structured interviews, unstructured interviews and group interviews with the teachers.
- Group discussions: This refers to set both student and teacher juries discussing the design problem.
- Verbal protocols: This requires protocol analysis and includes the observation and interpretation of a designer's (or the teacher's) behavior in design process step by step.
- Observational studies: This requires the observation of a designer or the teacher in design process.
- Expert or novice simulation: Imitating the design strategy of the observed designer is a kind of simulation.
- Interactive prototyping: Teacher and student can work together to define the knowledge base. This might be a report or an article, as well as a Knowledge Based System.
- Questionnaires: These are the documents used by the students to extract expertise from the teacher.
- Self-elicitation: This is the elimination of domain knowledge from others.

AN APPLICATION OF COMPUTER BASED LEARNING IN DISTANCE EDUCATION

Virtual design studios enable designers to collaborate, communicate, and share design ideas with each other in different locations and time zones. Virtual Design Studios create efficient design environments for distance education. Istanbul Technical University and the University of Sydney established VDS'2000 (Cagdas et al., 2002) between Turkey and Australia to analyze the nature of computer based learning in a virtual design studio. VDS'2000 introduced the students to the idea of a Virtual Design Studio in which the Internet communication and information sharing technologies and the World Wide Web are the means for project coordination and documentation. Eleven Turkish students collaborated with six Australian students for the design of an Olympic village. The students learned how to set up and run virtual design studios and how to apply the technologies supporting these studios. These technologies included 3D modelling, electronic communications, and Internet technologies for collaboration. The design teams, which constituted at least three students from both institutions, worked in collaboration, and each team produced a documented design project. The project teams worked not only in Netmeeting (video conferencing - Fig.7), but also in ActiveWorlds, (virtual reality package - Fig.8), to design O'live 2000 for the Olympic Games in Sydney.

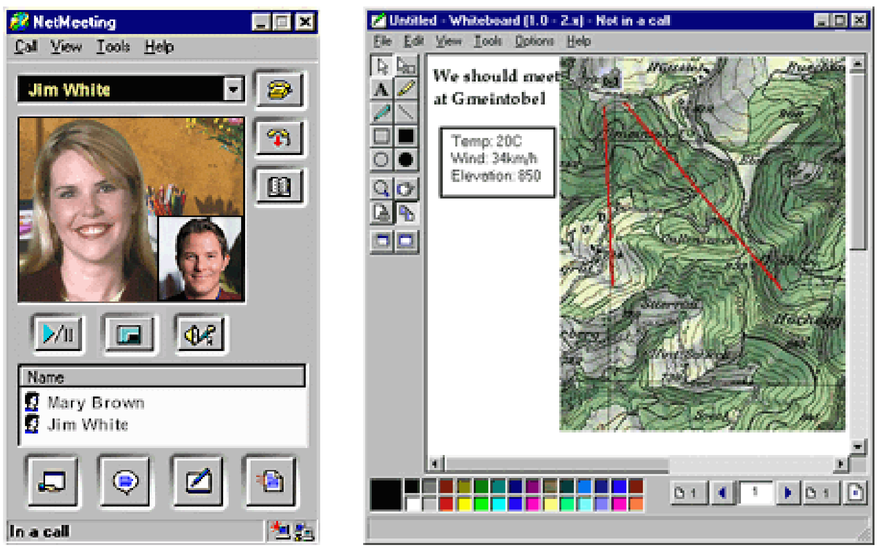

Figure 7. Netmeeting environment used in VDS'2000

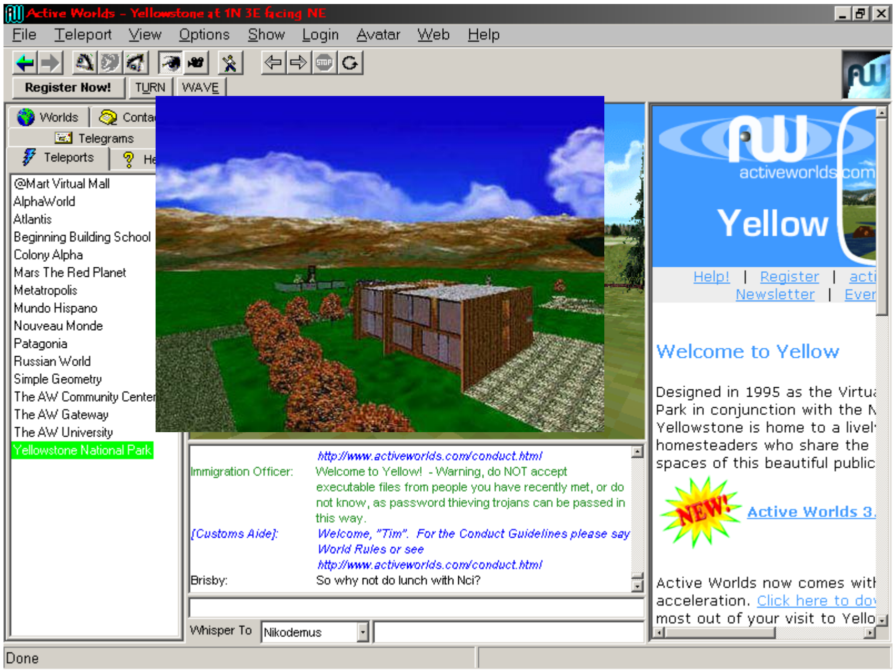

Figure 8. ActiveWorlds environment used in VDS'2000

In VDS 2000, the aim was simply to teach the design collaboration in a virtual environment by using digital technologies, rather than to search for ways to enhance the design quality and creativity. The approach used was knowledge acquisition from shared information online. The students in VDS'2000 were not instructed about how to design an Olympic village in a 3D world. Instead they were observed -in the design process- adopting an active learning strategy. The materials given to the students were as follows: Site, Design Brief, Schedule, Project Presentation Procedure, Assessment procedure, and Assessment criteria. Besides these, the following information was given to the students: the VDS concept, VDS samples, Online Tutorials for WEB pages, and Online Tutorials for Active Worlds.

The major characteristic of design education is its dependency on face to face communication and table critics. Instead of this, in VDS'2000, the communication between the teams was achieved at a distance in both asynchronous (e-mail and web pages) and synchronous modes (video conferencing and online chat in Active Worlds). The students were required to structure their ideas by establishing a web site for knowledge acquisition of distant partners. They placed various information about the design project as well as their approaches in this web site. They collected and shared information about previous Olympic villages as well as the Olympic village in Homebush Bay, Sydney through this web site. Their design scenarios, design concepts, design criteria, as well as the design proposals were displayed in their individual web sites.

Approximately 90% of the students had no previous experience with designing web pages, however they could cope with the demands of distant collaboration in a virtual design studio. At the end of the study, the students in VDS'2000 reported that they enjoyed learning in this game-like learning environment (Cagdas et al, 2000, 2001, 2002). In VDS'2000, as a pilot study, we used a number of knowledge engineering methods: interviews (structured and unstructured interviews, group interviews with the teachers), group discussions, interactive prototyping, and self-elicitation. In future, we will test the usability of observational studies, expert or novice simulations, and questionnaires yet to prove our hypotheses.

CONCLUSION

Research in cognitive science (Kavakli & Gero, 2001, 2002), regarding to the differences in knowledge structuring between novice and expert designers, has shown us that we need to find ways of teaching knowledge structuring strategies to the novices to raise their performance in professional practice. Research in virtual design studios (Cagdas et al, 2000, 2001, 2002) has shown us that the approach of structuring shared information in online documents was an efficient and enjoyable learning strategy. Then, why should we not teach knowledge structuring strategies to the students in design education, assuming students as knowledge engineers building themselves (Kavakli, 1996, 1998, Kavakli & Schindler 1996)? In VDS'2000, we have tried using a number of knowledge engineering methods and the result was successful as an active learning strategy.

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M. Kavakli and J. Thorne
School of Information Technology,
Charles Sturt University,
Bathurst, NSW 2795,
Australia
e-mail: mkavakli, jthorne@csu.edu.au