LEARNING THROUGH STRUCTURAL ACTIVITY IN COLLABORATIVE COMPUTER-AIDED DESIGN

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Abstract. The role of structural activities and other solution searching activities in design learning and problem solving have been identified in laboratory studies of problem solving and also in case studies of design teaching.. In laboratory studies, students have solved creative problems collaboratively under various communication conditions. The case studies follow students working on the same problem under two conditions – one group is taught using traditional face-to-face teaching while the other group is additionally supported by a text-based web board. This paper review findings from three experiments from which we can see that students producing above average solutions involved more structural activities than the mediocre cases. These successful cases engaged in textual expression of their design solutions. Computer tools for design should therefore support multiple representations of design work.

1. Introduction

Computer support for collaborative design has focused largely on the synchronous communication of graphical information, supported by file exchange and video channels in addition. The use of these tools has been reviewed and the assumptions challenged. Collaborative design can be better understood as asynchronous and synchronous activities together in which a number of communications channels can be beneficially employed, with video and synchronous drawing often inhibiting creative output (Kvan 1997, Vera et al 1998). The role of representational modes in CAAD other than graphics has been review elsewhere (Lawson & Loke 1997). The need for a more diverse range of design learning support in virtual studios therefore deserves more attention. The concept of structural support of design has been explored and finds relevance in the specification of virtual design environments.

Problem solution is affected by problem perception (Newell & Simon 1972). The uniqueness of design as a problem solving activity lies in the possibility of unlimited number of solutions (its ill-formed nature) in contrast to the well-formed nature of a geometric problem, for example. The range of design solutions presented in a class can therefore vary drastically if students frame their understanding of the problem in different ways. In the sequential nature of design exploration (i.e. time sequential, not thought sequential, the framing of earlier problems will have an effect on later sub-problems (Akin 1986). Appropriate problem representations can aid the identification of creative solutions (Holyoake 1984). Some representations will be more effective than others (Mumford et al 1994). These findings are confirmed in design research, re-representations of design concepts and solutions are essential to successful design (Goldschmidt 1997, Eisentraut 1999). Such representation allows for concepts to be compared, joined, transformed or interpreted. In studio learning terms, this implies that re-representation supports better understanding of the design problem at hand.

If this is the case in design tasks, can the findings help us in our preparation of collaborative design environments intended for learning? With a growing interest in virtual design studios between different universities (as demonstrated in the proceedings of almost every CAADRIA, eCAADe or ACADIA conference in the past ten years) and the development of online virtual teaching environments (Maher Simoff Gu & Lau 2000), we need to consider the tools made available to participants in the collaborative design learning context. To this end, three sets of experiments have shed light on the tools we might include.

2. Collaborative Problem Solving

Collaborative online design exercises are established in schools of architecture with a number of intended outcomes: exposing students to the new working environment of online collaboration; supporting off-campus learning; increasing cultural exposure (Bradford et al, 1994; Maher Simoff & Cicognani 2000). To this, we can also add the opportunity to learn more effectively (Kvan Wong & Vera 2002). Before identifying implications for collaborative design learning environments, let me first summarize relevant recent experimental findings from our recent research.

2.1 IMPROVING INITIATION OF DESIGN IDEAS

An earlier study of architectural design was reported in Kvan Yip & Vera (1999). In this study we investigated the relative roles of textual and diagrammatic representation in a collaborative design task. Two different conditions are established. In one, the participants are asked to communicate

by chat line and are allowed to draw on a whiteboard as they seek to collaboratively resolve the design problem. The product of this collaboration is a sketched solution. In the second condition, the participants are asked to explore the design and come to a proposal only through the chat line, then write up a proposal in text form. Those in the text only condition were given an additional 5 to 10 minutes after the experiment to translate the text description into a diagram without modifying their ideas, allowing us to confirm that a shared understanding had been arrived at in text mode. We could also then compare the final drawing with those in the other condition. With this setup, we seek to identify the effects of text versus diagrams in the collaborative design task when the bandwidth is limited to 'chat-line' conditions.

The full details of the research conditions have been described elsewhere. In the course of the experiment, communication protocols were collected. The protocols of these experiments were coded by the authors to identify the initiation of ideas during design collaboration. To do this, protocols were coded to identify when new ideas were introduced into the communication. New ideas were defined to be (1) an idea not yet mentioned; or (2) a fundamental reinterpretation of an idea in play. Table 1 shows the raw number of initiations and total communications during the experiments.

Table 1: Initiations of ideas
(total communications in parentheses)

Diagram allowed	Text only
3 (61)	10 (90)
4 (55)	21 (105)
	13 (82)

From this encoding, it was found that chat line participants explored more ideas (% ratio of high level exchange initiated by subjects in the chat line conditions is larger than that of those in the audio condition in general) than those using video/audio. Thus, chat line appeared to promote a richer exploration of the design problem space than video/audio environments.

2.2 IMPROVING LEARNING

While demonstrating the non-graphical communication can improve the generation of design alternatives, is there any reason to believe that such communication can affect learning. This postulation is supported by the work of Yip (2000) in which she investigates the effects of learning in the solution of isomorphic logical problems, not design problems. In her studies, she adopted isomorphic Tower of Hanoi and Monster and Globe problems

(Kotovsky Hayes & Simon 1985). Subjects were paired to work collaboratively in either text or diagrammatic conditions. Since the problems are isomorphic, it is possible to examine whether any learning has occurred when the pairs solved the second problem. The results demonstrate that the text only condition was better for solving these problems and, most importantly, that the text only condition showed clear support for learning. Subjects using the text-only condition formed better hypotheses, made fewer wrong moves and violated fewer rules than those working in the other condition while solving their second problem. This set of experiments illustrated that the text condition supported learning.

2.3 IMPROVING STUDIO LEARNING

Taking these experiments into the design studio itself was the next step. As reported in Kvan Wong & Vera (2002), a design studio was established in which students were formed into two groups and a design studio problem given as part of the normal sequence of second year undergraduate studio teaching. The same design topic was given to both groups. Teaching was conducted in the normal manner of design studio – desk reviews, pin ups, individual and group discussions (Schön 1985). One group was supported in addition by a web board that was used for daily communication between tutor and students as well as between students themselves. Access to the board was freely available and all postings visible to all participants in the second studio group.

At the end of the studio session, design products from both groups were independently evaluated; no difference was found in the results, suggesting that both groups were able to complete the work equally as well. The students in both groups were interviewed extensively throughout the semester as well as at the conclusion of the project. The web board supported group used text extensively in their work, although not uniformly. Some students used more text that others, both in their web board communications and also in other media such as annotating paper based drawings. We analyzed the use of text in all its forms more extensively and identified two important findings from these observations: the students who used text examined more alternatives (as suggested by findings noted in 2.1 above) and they exhibited better learning than those who worked only in the conventional studio mode of sketching and drawing. Text had been used by the students as a tool of re-representation and exploration; those who explored more ideas and re-represented these ideas more often appeared to have better design results than those who simply drew and talked with their tutor (in agreement with Fricke 1999).

3. Implications for Online Collaboration

Structural activity can be defined as the restructuring of ideas and meaning through representation. From the work described above, structural activity is an essential part of successful design work. Learning appears to be reinforced by structural activity. Computer-supported collaborative design environments do not enable a rich variety of structural activity due to their restricted range of tools and working processes supported. Thus, we can reconsider virtual design studios to improve learning opportunities.

What do these experimental and studio results suggest to us for computer-supported collaborative design environments? First, it suggests that synchronous audio / video environments are not supporting learning as well as those in which students have to describe in words their intents. Secondly, computer tools that are focused on graphical representations, such as conventional CAD systems or sketch tools, must be supplemented by non-graphical tools. Thus, the environment for learning design collaboratively across a computer network should not be a simple replication of the face-to-face environment but should take advantage of the opportunity to reinforce learning. The tools should support learning and design development through the structural activity of re-representation. While most students may do this through making models, in an online collaborative world this is not so easy. The modes of communication available to us reinforce the value of textual communication as a means of re-representation.

It is not easy to use this combination of tools. In face-to-face teaching, tutors can switch between modes of verbal description and graphic representation without effort. Asynchronicity makes this less easy; we do not have tools to record oral descriptions while we drawn. Importantly, though, as Olson (1996) notes, written text requires more substantial consideration of the meaning and is a better support of learning. It suggests that three aspects of virtual studio planning deserve attention: the selection and configuration of tools to be provided; the specification of the design problem to be attempted; and the sequencing or phasing of activities during the studio period. Each of these should accommodate the need for multiple media and present opportunities for restructuring of the design solution. A phased studio can be composed to support a phasing of tasks, leading students more carefully through steps of design exploration from initial exploration through to design presentation, explicitly requiring them to describe the design in many modes rather than remaining in the graphic world.

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