Supporting Design Studio Learning: An investigation into design communication in computer-supported collaboration

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Abstract: Earlier studies suggest that benefits may be found in chat line communication rather than high bandwidth video-conferencing conditions when considering collaborative design learning. This paper draws together studies that look at this conjecture and concludes that chat line collaboration reduces fixation in problem space exploration. This encourages the participants to explore design opportunities in a different way than graphical or video based communication.

Keywords: design learning; collaborative design; text communication; architectural design

1. Introduction

As the reach of the Internet expands and technological tools become more readily available and affordable, there is rapid growth in research into computer-mediated work and groupware. Computer supported collaborative work (CSCW) has come to be applied to a wide variety of fields, including collaborative architectural design. Several universities have recently engaged in virtual design studios in which students from a variety of remote locations join together and engage in joint design studios. This work has proceeded without an understanding of the pedagogical or technological contexts within which it is placed.

Traditional architectural studio teaching is based on the notion that successful design solutions and design learning are a direct outcome of the extent to which the design problem space is explored (Schön, 1987). This suggests that learning environments for design should support wider exploration of the problem space and reduce fixation on lower level aspects of the problem. Additionally, the contribution of text in creative design has been argued elsewhere (Lawson & Loke, 1997) but the mechanism of its contribution not explained. This study attempts to illuminate the contribution.

2. Supporting design learning

The importance of collaborative learning is well documented. For example, it has been noted that students who worked in pairs learned more effectively than individuals across ability groups (Hooper, 1992). Narayanan, Hmelo, Petrushin, Newstetter, Guzdial & Kolodner (1995) have constructed an extended framework for collaborative learning, suggesting five central tenets for learning, including the idea that a shared electronic

workspace that seamlessly integrates a full variety of functionalities will 'scaffold' and enhance learning.

When examining collaborative design learning in a computer-mediated environment, we must examine not only learning but design. Here we find that a belief that social processes play a critical role in design communication is often unquestioned. This belief is carried to the extent that some research (e.g. Fitzpatrick, Kaplan & Mansfield, 1996) assumes that design collaboration can only be understood in terms of its context. This, in turn, leads to the assumption that successful collaboration can only be achieved if the communication media attempt to replicate, through high bandwidth, the conditions found in face-to-face experiences. Hollan and Stornetta (1993) have highlighted the difficulties in this assumption and the failures of attempting such replication. Such an assumption fails furthermore to credit other conditions for their positive contributions.

2.1 Earlier studies

Our research group has been looking at design studio teaching and learning in computer-mediated communication (Kvan, West & Vera, 1997; Vera, Kvan, West & Lai, 1998). In earlier studies, we have explored the effect of bandwidth limitations on collaboration and the consequent interface implications. Specifically, we examined whether low-level and high-level design concerns are consistently present in design discussions regardless of the nature of the interface. Additionally, we have also evaluated whether any such differences that might arise have an effect on the quality of the completed architectural design.

The results of these studies have shown that the quality of the final design solution, and the performance of the collaborating designers is similar in both chat line and video/audio enabled communications. They found that the percentage of exchanges for the collaborative problem solving steps of Meta-planning, Negotiation and Evaluation are very similar under the two different communication conditions. This suggests that the collaboration process would not be affected by the bandwidth of the communication channels. Participants simply adapt to the low bandwidth condition by reducing the amount of the exchanges proportionally in each step.

Importantly, the studies found that the ratio of high versus low-level design exchange is **reversed** for the chat-line and video-conferencing conditions. They showed that participants maintained the same amount of high-level design exchanges in the low bandwidth condition by cutting down the low-level design exchanges as well as other design irrelevant exchanges. Participants who have limited available bandwidth focus on the task. This interesting result suggests that chat-line may better support collaborative design learning than higher bandwidth conditions. The results also suggest that participants adapt to the environmental constraints by adjusting the ratios of different levels of communication without sacrificing the quality of the product. These findings here are consistent with other studies beyond design collaboration (Kraut, Miller & Siegel, 1996; Olson, Olson & Meader, 1997).

The ëPlaygroundí study

Another study was carried out to further investigate the effects of bandwidth, and its relation with the knowledge domains. In this study, eight educational psychologist students were paired up with eight architecture graduate students to work on a kindergarten playground design task collaboratively. They were randomly assigned to work in either a chat-line or video-conferencing condition. A shared drawing board is always available for communications and presentations of the design solutions. The protocols collected were coded and analyzed according to the two models proposed in Vera et. al. (1998). The results found are consistent with the earlier studies. When coded with the ëCollaborative Process Modelí, the percentage of exchanges of each step is similar for both chat line and video/audio conditions. The amount is reduced proportionally for the chat line conditions. However, when it is coded with the ëDesign Process Modelí, the ratio of high versus low-level design exchange is reversed for the chat-line and the video-conferencing conditions. Furthermore, this pattern is consistent over the architectural students and the educational psychology students, suggesting that the effect is mainly due to the bandwidth of the collaborative environment, instead of the knowledge domain of the subjects.

Table 1: Proportion of exchanges in the playground study, coded according to the ëDesign process modelí:

	Interface	Task focus	Low level design	High level design
Chat line (expert)	8.57%	15.24%	24.76%	51.43%
Chat line (novice)	2.88%	22.12%	25%	50%
Video audio (expert)	11.01%	10.31%	49.54%	29.08%
Video audio (novice)	9.38%	10.97%	53.42%	26.23%

Additionally, the final design solutions were evaluated by two architects and two educational psychologists respectively. Using similar evaluative methods and criteria as in the first study, the architects found no significant difference between the two conditions. The educational psychologists devised a set of evaluation criteria relevant to playground design and applied these to the designs. There were again no significant differences between the designs produced in each condition, except when using the criterion of ësafetyí. In this dimension, participants in the chat line condition were found to produce better design solutions. This result suggests that chat line **may** allow for a better collaboration than the audio/video conditions.

2.2 Initiating Ideas: A richer design exploration

As noted above, results from the earlier studies suggest that textual communications play an interesting role in the solution of collaborative design problems. The fact that the ëreversal effectí exists in the chat-line condition led us to seek an explanation for it. Also, the notable result found in the playground study, showing the possible benefits of using chat line to solve the collaborative design problems, was considered worthy of further examination.

A follow-up study was therefore initiated to explore the particular properties of text communication in design. In this second study we investigate 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 ëchat-lineí conditions.

In keeping with the earlier experiments, the subjects for this study were ten students completing the fourth year of a five-year professional architecture program at the University of Hong Kong. They were set tasks to be completed collaboratively in pairs while sitting in two adjoining rooms, each equipped with Pentium computers. Both computers were equipped with Microsoftís NetMeeting, which supports collaborative work by providing a shared electronic white board and a chat line. The computers were connected through a local network; all the connections passed through the wall so that, with the door in between the rooms shut, subjects were cut off from any direct communication and had to collaborate through computer supported communication, either graphic or textual. Transactions on the computer screens were captured on to videotape using the "AverKey300" system. By this means, all the activities on the computer screens were recorded throughout the whole experiment session for later reference. Additionally, text and graphic results of the sessions were saved to disk. NetMeeting logged chat line communication. All these data were used for later analysis.

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 2 shows the raw number of initiations and total communications during the experiments.

Table 2: 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.

Although not enough participant pairs have been run to allow statistical analysis, the trend is very clear. Subjects in the text-only condition have richer design explorations than those in the diagram conditions, with text-only descriptions producing almost 16 new ideas per hundred utterances in text compared with 6 new ideas for every 100 when a diagram is allowed. The absolute numbers are even more stark - text-only pairs explored up to five times as many ideas as those using diagrams. Thus, the protocols indicate that participants using diagrams to support their design exploration may be fixating on ideas whereas those using text alone work their way through a variety of concepts in the time allowed. This suggests that a text environment may have unique properties in encouraging design students in more divergent thinking and to be less bounded by the diagrammatic representations of ideas as they are being explored. The results also suggest a possible explanation for the finding in earlier studies that chat-line provided better support for collaborative design.

3. Summary

These experiments help to identify one mechanism by which text is contributing to design. Our data show that participants in the chat line condition not only limited their low level exchanges as noted in the earlier experiments but also that their high level exchanges explored more ideas than in the video/audio condition. In the latter, the participants engaged (and became mired) in more discussions of lower level details of the problems. Those in the video/audio condition were found to oscillate between high and low level discussions frequently, whereas those in the chat line condition remained more consistently in the realm of high-level design discussions.

An explanation of this phenomenon can be found in the concept of fixation. Those in the video/audio condition are working in an environment in which they can work in parallel when communicating by voice and drawing on the shared whiteboard. Thus, we

observed, the video/audio condition allowed participants to divert their design collaboration from discussion about a high level idea into a low-level exchange about how to represent the idea. For example, an idea of placing a set of play equipment would quickly devolve into a discussion about whether to represent these with circles or squares, blue or red, the larger topic forgotten or swamped by the implementation details. A similar outcome is found in those participants able to draw and type in the second experiments. Participants in the text only condition were required to focus on the content of the text as the idea emerged, then transfer their focus to the representation of the idea in text too. As a result, the ideas were explored more consistently at the higher level.

From these results, it appears that chat-line communication encourages divergent thinking and exploration of ideas. The limited bandwidth of a chat line 'scaffolds' the learning in a simple manner, without requiring an extensive and broadly capable environment as suggested by Narayanan, et al. (1995). This is attributed to the discovery that the more restricted text-only environment encourages participants to explore the problem space more inventively than those who had access to a shared drawing surface during their collaboration. This suggests that a restricted bandwidth condition may be a useful tool during design learning to encourage a different form of design problem space exploration than that allowed by high bandwidth contexts.

Findings so far indicate a number of directions for further investigation. We are in the process of running more subject pairs in each condition of Study 2 as well as in two similar conditions where participants are first year architecture students rather than fourth year. This will allow us to directly assess the covariation between knowledge and the medium of communication. This may yield some clues on how and what to teach design students, for example, requiring the students to explore the design problems in text form only. Another study to be carried out in the near future will examine students tackling ëisomorphí problems collaboratively, allowing us look at the learning process directly. By investigating learning performance in solving isomorphic presentations of families of problems in both textual and diagrammatic contexts, we can further understand the different functions of text and diagrams in learning.

These results have also been applied to design studio teaching. Teaching in a second year design studio has been restructured to use a web board as a medium of communication between students as well as with the design tutor. Students have been asked to use the web board and associated chat line to discuss the design problem set and to record ideas. As the semester progresses, they will be asked to review logs of the chat line and the web board postings to explore the design discussions engaged earlier. Based on the findings above we expect to see students initiating ideas in the text chat line, although most likely not exploring them in depth at the time they are initiated. By virtue of the logging of all chat and bulletin board communications, the students will be able to review these exchanges and identify ideas dropped or forgotten. This can then be brought into the learning process and we expect students to review a broader problem space than colleagues who will not be using the web technology.

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