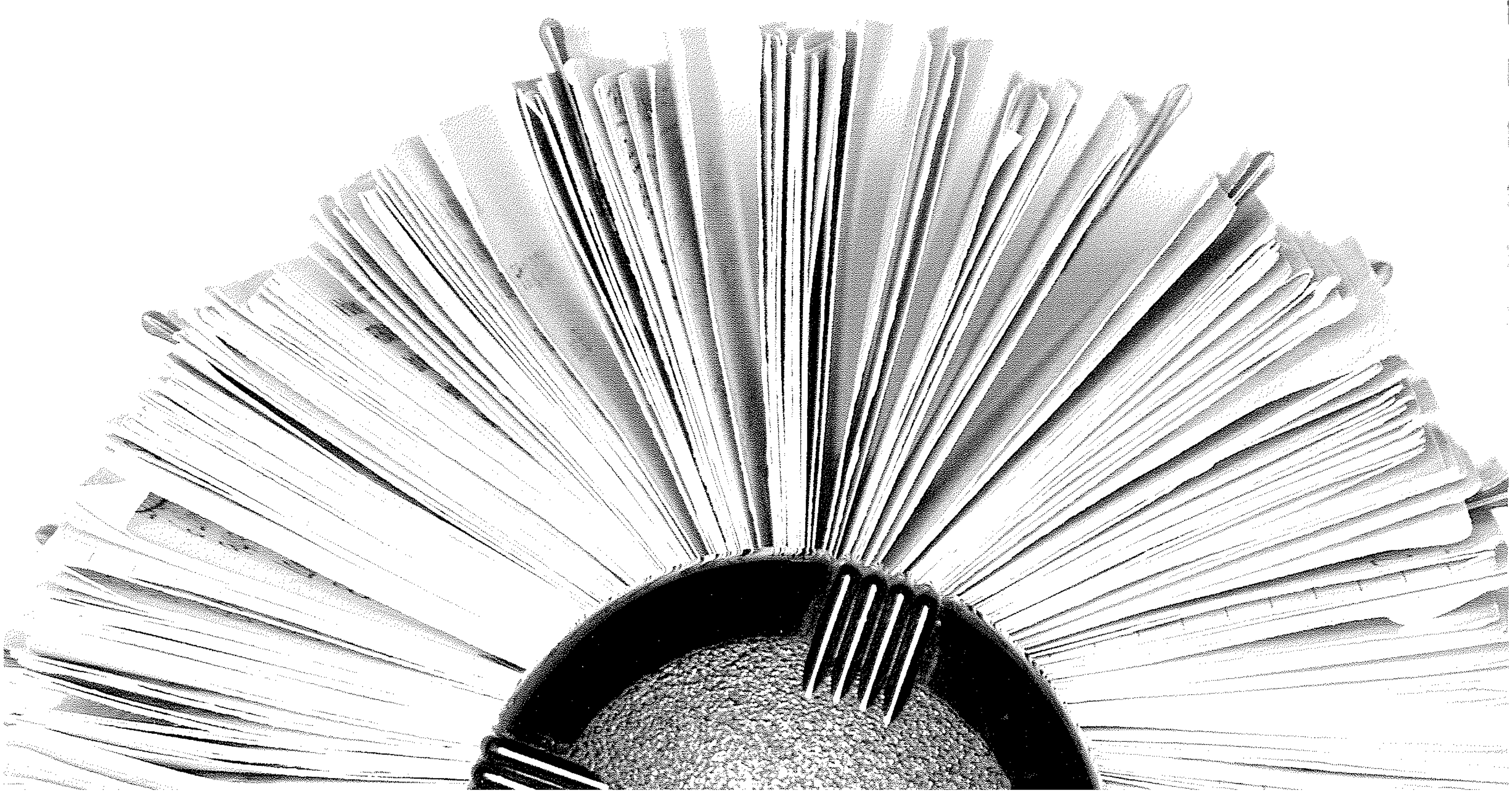
Sharing Tacit Design Knowledge in a Distributed Design Environment

Jeong-Han Woo
Mark Clayton
Robert Johnson
Benito Flores
Chris Ellis

Texas A&M



The AEC industry has realized the value of capturing, storing and reusing architects' design knowledge that is mostly tacit. Tacit design knowledge is highly personal and implicit knowledge. As such, it encompasses design capacity, expertise, intuitive understanding, and professional insight formed as a result of design experience. Throughout the life cycle of a design project, architects rely heavily on their tacit design knowledge to support design decisions (Schon 1983). Therefore, to achieve greatness, architectural firms try to hire good architects with in-depth design knowledge and expertise. Ron Skaggs, Chairman and Past CEO of HKS, has stated that the employee is HKS' greatest resource (Skaggs 2002).

Current architectural design process has been described as a multi-participatory distributed design environment (Huang 1999) to which architects bring their own expertise from remote locations. Architects' tacit knowledge holds tremendous value if made reusable for the right project at the right time. Therefore, the firms' main concern is how to hire accomplished professionals who will apply their architectural expertise to projects at the right time.

In a large architectural firm, work is sometimes duplicated because people are unaware of each other's work in remote locations. Consider a senior architect in a Dallas, TX, office who previously conducted several office building projects and a novice architect in Tempe, FL, office who is developing an office building design for the same client. These people could share extensive information if they were aware of one another's work and connected at the right time.

Due to its implicit nature, tacit design knowledge is typically shared only among colleagues who work in the same office through face-to-face interactions. One way to share tacit design knowledge is to encourage architects to engage in more informal conversations as a form of "Communities of Practices" (Brown and Duguid 1991). The essence of informal conversations is a cooperative attitude that fosters collaborative work on projects. They can share and synchronize information and design knowledge among themselves.

Furthermore, with emerging CMC (Computer-Mediated Communication) technologies, architectural design process faces new opportunities for capturing and reusing tacit design knowledge. The information systems of an architectural firm could support these perspectives, not merely exchange drawings or documents. Intranet or Virtual Private Network (VPN) could incorporate CMC technologies to allow individuals to talk to each other informally. However, there is no accepted and guaranteed CMC strategy for managing tacit design knowledge in the AEC industry.

This paper elaborates the concepts of design knowledge sharing in a distributed design environment by documenting close empirical observations in a graduate level architectural design studio. This paper further investigates the impact of tacit design knowledge that has been captured and shared using online, interactive chat-based software that was developed by the researchers.

The software was tested in a graduate level architectural design studio in which design students sought advice from experts in remote locations. The design studio required students to address highly technical topics outside their previous education, such as sustainable construction, cost and constructability analysis, and landscape design.

Content, time, participant characteristics, and other data from chat sessions were recorded and documented. The data were analyzed using qualitative and quantitative methods, including content analysis, protocol analysis, logs, frequency counts of dialogues, simple statistics, and questionnaires.

Literature Review

Reviewing the extant literature on theories of tacit knowledge, virtual design studio, and CMC technologies elaborates theoretical foundations and provides some preliminary answers to these unexplored questions: How can CMC assist in capturing and sharing experts' tacit knowledge? What are the problems associated with the integration of CMC into a distributed design environment?

Theory of tacit knowledge sharing

Few researchers in the field of architecture have rigorously studied the importance of tacit knowledge sharing in architectural design environments. However, Schon (1983) convincingly demonstrates that experts' tacit knowledge is a very important resource in the architectural profession. He explores the traditions of the architectural studio to investigate how architectural students learn from instructors in a design studio, insisting that design knowledge can be shared by reflective conversations within a design situation. Suwa et al. (1998) also stress the importance of tacit knowledge in the design profession, especially in an educational sense. Likewise, Cross and Cross (1995) conclude that the knowledge sharing process of design significantly influences the quality of design.

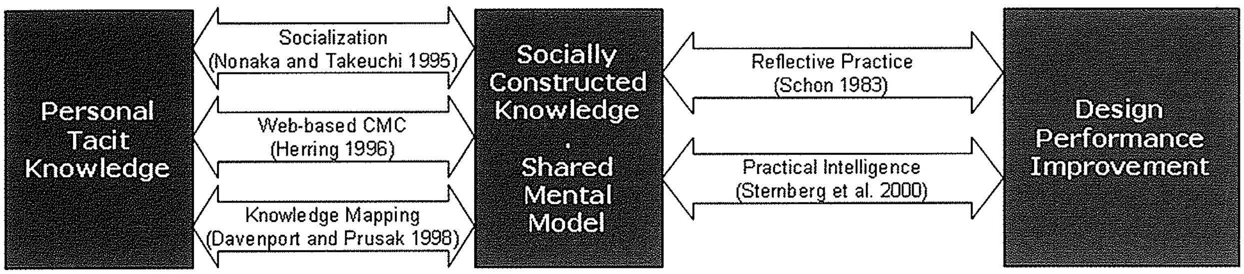


Figure 1. Theoretical Background

CMC technologies in a distributed design studio

In the field of CMC research, a few articles (Isaacs at el. 2002; Ribak at el. 2002) report several key findings where online chat or instant messaging systems successfully support tacit knowledge sharing in a typical business environment. They also argue that CMC could improve access to tacit knowledge and might offer an organization a competitive advantage by improving its efficiency and expertise.

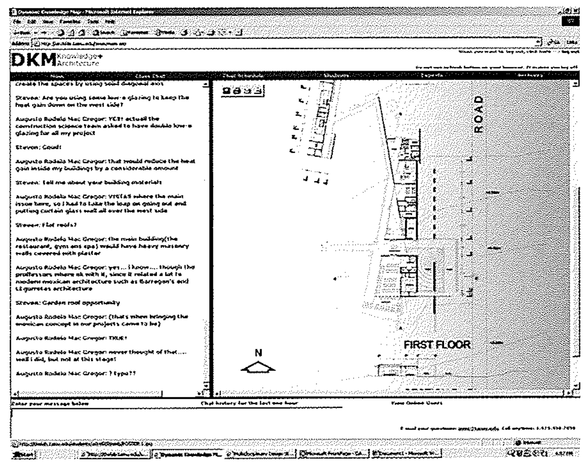
A major limitation of current architectural research is that little research examines the potential of CMC to support architectural design processes in a distributed design environment. Few design studies have been conducted concerning the effects of CMC on the architectural profession. Huang (1999) studied the implications of collaborative media on design process by employing organizational economics theories. Kvan and Candy (2000) conducted experiments to investigate the role of CMC technologies on collaborative design communication over computer networks. In their study, chat-based software played a significant role in producing effective design communications. However, their research does not explore the impact on the design artifact of reusing tacit design knowledge; rather, they focus on facilitating design communication.

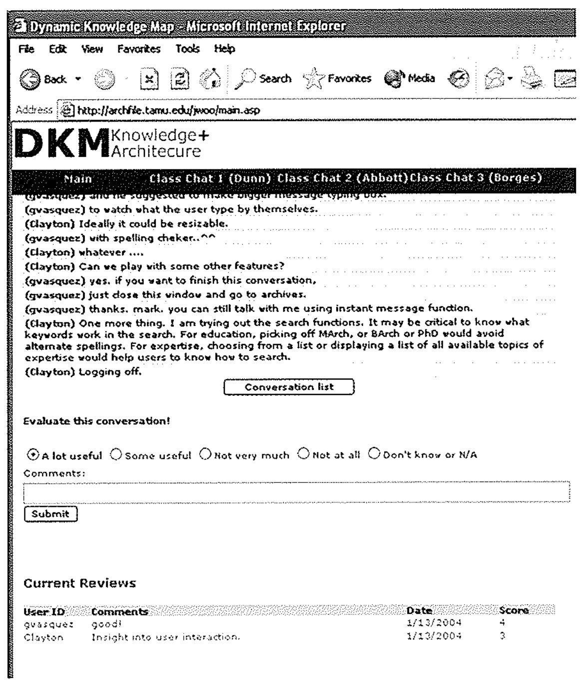
A main concern among observers and researchers is how CMC technologies might affect design performance. Maher et al. (2000) conducted an experiment in a virtual design studio to compare face-to-face communication with CMC communication to test how CMC technology changes the process of design communication. The findings indicate no significant difference between face-to-face and CMC communication. The results of these studies partially support the premise that design communication could be increased by using CMC technologies for virtual knowledge sharing.

Based on the literature review, a theoretical model (see Figure 1) was initially developed by combining and extending of the work of Davenport and Prusak (1998), Schon (1983), Sternberg et al. (2000), Nonaka and Takeuch (1995), and Herring (1996). The theoretical model shows that knowledge sharing starts with the identification of an appropriate knowledge holder, which involves the concepts of knowledge mapping (Davenport and Prusak 1998). Nonaka and Takeuchi (1995) insist that a process of sharing tacit knowledge lies in the socialization which create socially constructed knowledge and shared mental model. Herring (1996) focused research on the use of Web-based CMC for knowledge sharing. By accessing socially constructed knowledge, job performance could be improved as a form of practical intelligence (Stenberg et al. 2000). This theoretical model was later revised by interpreting the research results at the conclusion of this study.

Figure 2. Screen Shot of a Chat Session

Figure 3. Screen Shot of the chat Archives and the Grading Function





Research Overview

The intuition behind the research is that rich telecommunication systems provided by the Internet can be a successful way to convey tacit knowledge about architectural design. A review of literature and theory supports this intuition and helps define a theoretically attractive software environment of Internet-based chat that is enhanced by graphic and visualization tools, supported by a database system, and delivered through Web technology.

To learn about how such a tool affects the exchange of tacit knowledge, an experiment was conducted in the setting of a graduate design studio in a College of Architecture. The experiment required the invention of a software tool and its implementation on the college network. Students used the software to seek tacit knowledge to apply to their design projects by communicating across the Internet with design critics. The documents recorded by the software were used in conjunction with demographic data and interviews to draw conclusions about the use of the software to support tacit knowledge exchange during a design project.

Software

The software used in this study was designed to demonstrate new methods of sharing tacit design knowledge that include locating, selecting, and communicating across the internet. One major function is to support synchronous chat with design experts as they offer design knowledge while simultaneously sharing architectural images (see Figure 2). Software users can also search for experts using categories of expertise, key words, and indexed transcripts of chat sessions. The system then facilitates communication with those experts though chat sessions.

All dialogues are saved in a database as records of tacit knowledge sharing, and make accessible for a knowledge seeker to retrieve them for subsequent use of tacit knowledge conveyed in the dialogue. In addition, a grading function enables the system to develop a sense of the usefulness or reliability of experts on various design topics (See Figure 3).

Methods

The instrumental case study approach (Stake 1995) was used in this research. The aim is to provide a description and understanding of what happened during design sessions by conducting formal observations and an in-depth analysis of data. In this research, two design studios were selected as cases to gain in-depth insight into design knowledge sharing processes. This paper presents the results of the first design studio only. The results from the second case will be presented in future reports.

The impact of tacit knowledge sharing cannot be judged by a single criterion due to the complexity of knowledge transfer processes. Stake (1995) also emphasizes the importance of multiple data sources in an instrumental case study to provide multiple perspectives and increase reliability. Therefore, data were collected and analyzed using both qualitative and quantitative methods to enhance the validity of findingsthrough content analysis, log files, timestamps, simple statistics, and questionnaires. Quantitative data such as questionnaire results, log files and counts of frequencies of software use will supplement qualitative observational data to triangulate evidence, producing more valid conclusions.

Setting

The case study was conducted in a graduate-level multidisciplinary design studio at Texas A&M University, College Station, TX, during spring 2004 semester. The design studio undertook a design project for the long- term planning and design of facilities at the Peckerwood Garden in Hempstead, Texas. The Garden is an outstanding repository of rare and unusual plants and unique folk art from Mexico and the United States.

The design studio was organized by three faculty members as a collaborative project involving each of the three departments in the College of Architecture: Department of Architecture, Department of Landscape Architecture and Urban Planning, and Department of Construction Science. Graduate students from the Master of Architecture, the Master of Landscape Architecture, and the Master of Science in Construction Management were enrolled in the course. The three instructors met with the students during the regular studio time. The design studio met twice a week for 6 hours per session throughout a 15 week semester.

As an additional communication medium, the software was introduced and employed by the students as a complement to traditional face-to-face design critiques. Numerous online design critiques using the software were conducted. In many instances, the online sessions involved practitioners or consulting professors who participated from remote locations. The computers used for the chat sessions are located in a college computer lab and typical, commodity personal computers. The lab is very convenient to use and has carefully been secured so that students cannot change computer configurations or network settings.

Participants

The participants included students, who may be thought of as "knowledge seekers", and design critics, who may be thought of as "knowledge providers." Twelve graduate students participated in the training and pre-test questionnaire. Of these initial participants, seven students participated in real-time chat sessions and completed the post-test questionnaire. The participation in the research was voluntarily and had no bearing on their course grade.

Category	Average	Max.	Min.
Age (Years)	25	29	22
Work Experience (Months)	16	30	0
Design Studio Experience (Frequencies)	11	20	6

Table 1. Characteristics of the Students

Seven design critics were selected and invited to contribute to chat sessions as knowledge holders. The design critics are leading faculty members, practicing architects, and industry experts. They participated using the Internet from remote locations, including other parts of the campus, Dallas, Houston, or Washington, DC. The design critics were recruited to enable students to gain tacit design knowledge at a higher level in a practical situation.

The preparation and training was planned carefully in order to have the greatest impact. Prior to the training session, a questionnaire was distributed to gain an understanding of the background of the participants and identify their demographic profiles.

The participants' average age was 21 years. They had one or two years of work experience and had previous experience on the same type of project. The pre-test questionnaire results indicate the demographic and educational background of the students as well as their work experiences (see Table 1).

Data

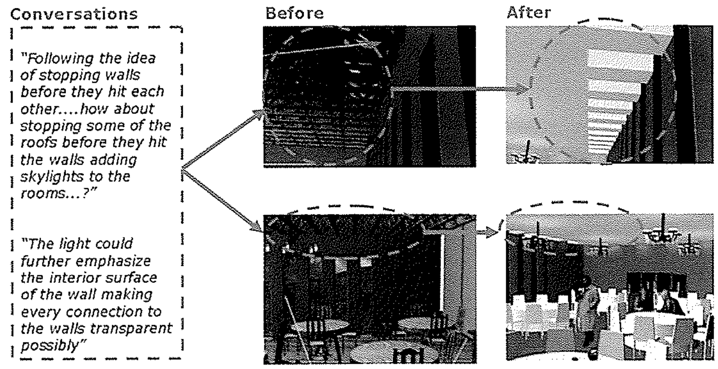
Two qualitative data sets were used for the content analysis: online chat transcripts and students' design artifacts. Content analysis of the chat transcripts and the design artifacts provides qualitative evidence for the effectiveness of the software for sharing tacit design knowledge. The online chat transcripts comprise messages between design reviewers and groups of students. The participants shared past design experience, professional recommendations and intuitive expectations. The chat sessions also included the identification, clarification and explanation of real problems. The records of dialogues show significant influences upon the students' approach to conceptual design.

Analysis of the chat transcripts consisted of an iterative search for design knowledge that was meaningful for the design projects. The students' design artifacts were comprised of drawings and posters produced in the design studio. Students' design artifacts were examined to discover any improvement resulting from the online chat conversations.

Quantitative data mainly supplemented qualitative observational data to triangulate evidence, which produces more valid conclusions by enhancing the internal validity of observational data. Two questionnaires were distributed to the participating students to collect quantitative data. The online student questionnaires consisted of 4-point Likert type and semantic differential scale check boxes. The submission of all questionnaires was completely voluntary and was not required by the instructors or the researchers.

Numerical data about actual usage of the software was collected by log files. These log files effectively recorded every action that every user performed within the software, including logging in and out; creating, joining, and leaving dialogs; and reading chat archives.

Figure 4. Student 1 example



Procedure

After conducting a training session for the students, the first questionnaire was made available on the first day of the experiment and collected descriptive data about students' attitude toward gathering design knowledge, previous design experience, tacit knowledge utilization, computer skills and the use of CMC. The questionnaire data were used to determine whether the student characteristics were initially equivalent on the questions, even though the groups were not formed by random assignment.

The design artifacts were collected twice: before and after the series of chat sessions. The second survey was made available on the last day of the design studio. The second, post-test questionnaire was primarily designed to obtain feedback about software usability, ideas and satisfaction. The relationships between variables in the sample were explored using simple statistics.

Findings from content analysis

Three cases of the online chat help to explain how the students applied shared tacit design knowledge to their design projects.

Student 1: Professional Recommendation

Student 1 is a 24 year-old male student with 9 months practical experience as an architectural intern in an architectural firm in the U.S. The questionnaire data indicates that he had the lowest usage of CMC technologies as compared to the other students. He had not used CMC technologies such as chat, instant messaging, and groupware for design projects at all. On the other hand, his data revealed the highest knowledge gathering attitude compared to the other students. He was also very interested in receiving critiques about his design concepts from practitioners in the industry.

A reviewer made a comment suggesting a different ceiling option to possibly add more skylights and enhance the visual quality of the space. Student 1 fully agreed with the suggestion and replied, "That is an interesting option which I had thought about earlier." He was also able to revise his 3D images quickly as shown in Figure 4. This revision indicates a clear illustration of transferring the reviewer's 'generalized tacit knowledge' into 'specialized explicit knowledge'.

Student 2: Identification of Real Problems

Student 2 is a 23 year-old female student with two years of previous practical experience in India. She has never used tacit design knowledge resources for her design projects. She never uses chat, instant messaging or groupware at all. According to the pre-experiment questionnaire data, she prefers to use asynchronized CMC technologies, such as email and Discussion Board. Since she holds a high tacit knowledge gathering attitude, she volunteered to participate in the first chat session.

Quite early in the chat session, the reviewers framed two problems. The problems were the narrow spacing between the buildings and the landscape design for the central garden area. The reviewers suggested creating wider spacing between the buildings. Another reviewer suggested celebrating the central landscaping area, thereby transforming it into a more meaningful space (see Figure 5).

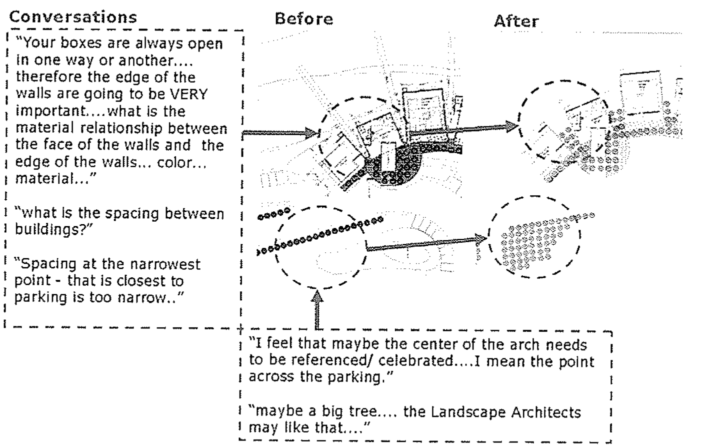


Figure 5. Student 2 example

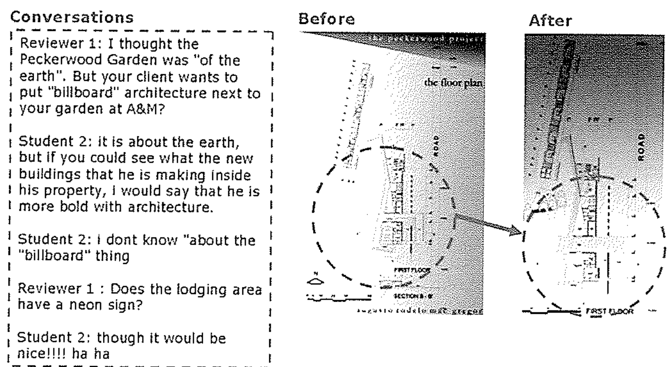


Figure 6. Student 3 example

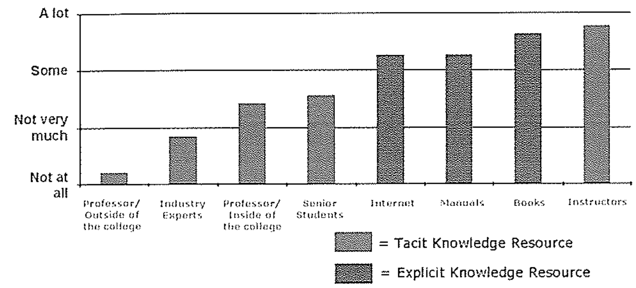
The reviewers' comments formed the most concrete evidence of the problem. Quickly, Student 2 framed particular problems that would influence the approach to developing a final design. Finally, Student 2 produced a revised floor plan which reflected the comments from the reviewers, as shown in Figure 4. In the end, she decided to integrate one reviewer's comments and changed the drawings. After the chat sessions, her perception of the chat session's usefulness significantly increased from "Not at all" to "Somewhat." Her overall evaluation of the software was the highest level—Very enjoyable.

Student 3: Mismatched Expertise

The following case shows the importance of just-in-time expertise matching. The reviewer is a director of USGBC (United States of Green Building Council), Houston Chapter, who has very extensive knowledge in sustainable architecture design. Student 3 is a person with design philosophy from modern architecture and high-level graphical presentation skills. He is also very positive about adopting technology and has plenty of experience using CMC technologies. However, his knowledge gathering attitude indicated "Not Very Much," according to the 4-point Likert scale.

In the chat session, Student 3 and the reviewer began the discussion from different perspectives and philosophical standpoints. Even though Student 3 did not seek advice from "green architecture" perspectives, the reviewer suggested an alternative decking option, composites, woods, and recycled plastics. The suggestions about the materials were not attractive for the student since they do not carefully consider the materials in a conceptual design stage. Although the reviewer has vast knowledge about sustainability, the student did not recognize the significance of sustainability for the project.

Although they spent much time discussing sustainability, Student 3 did not incorporate the comments into his project, as shown in Figure 6. Content analysis of this chat session suggests that just-in-time expertise matching, and a higher sense of cohesion might be very strong enabling factors for sharing tacit design knowledge in a distributed design environment. In the words of Student 3,



How do you get help on technical issues? (N=12)

Figure 7. Technology usage

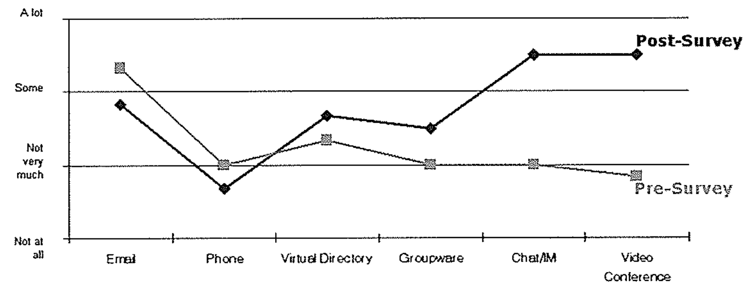


Figure 8. Perceptions of the integration of CMC technologies in design studios

"Experts need access to the history of the project such as who is the client, what are the goals, what skills or knowledge do the various students (or agents) bring to the project."

Findings from quantitative data

The analysis of the questionnaires and the log files is described in order to answer the following question, "How does the software assist in capturing and sharing tacit design knowledge?" In the questionnaires, most participants reported that their experience with the software was very enjoyable and the software is well-designed to support sharing of design knowledge. Participants indicate clear expectations that synchronous chat could be integrated with visual display, such as "mark-up systems."

Figure 7 illustrates that the students primarily use explicit knowledge sources such as the internet, manuals, and books when they need help on technical issues. Tacit knowledge resources, such as industry professionals, professors, and senior students, are not favored knowledge resources, even though they could provide very valuable knowledge. Instructors are definitely the most trusted resource since instructors assign grades.

The students varied in their perceptions of the integration of CMC technologies in design studios. The questions about CMC technology perceptions were asked twice in both questionnaires. Figure 8 shows the difference in the perception of CMC technology before and after the experiment. The perception of phone, groupware, virtual directory, and email stay the same. However, their perception about chat/instant messaging and video conferencing was greatly improved as shown in Figure 8. The results suggest further that students recognize chat/instant messaging as an opportunity to share tacit design knowledge and interact with others, not as a communication medium in which they only strive for facilitating faster communication.

Data from the questionnaires were used to evaluate the software and to consider how the software could be improved and implemented in a distributed design environment. Table 2 shows students' answers regarding their satisfaction with DKM. Significance statistics are not reported for the data due to the small sample size.

Overall, how would you describe your experience on the software?
Very enjoyable
2
2
2
0
0
0
0
Very frustrating

How would you describe your experience on the chat sessions?
Very enjoyable
2
2
2
0
0
0
0
Very frustrating

How would you describe your experience on the chat archives?
Very enjoyable
0
1
1
4
0
0
0
Very frustrating

Overall, is the software well-designed to support sharing of design knowledge?
Strongly Agree
0
4
2
0
0
0
0
Not at all

Overall, do you think that the software is useful to improve your design project?
Strongly Agree
1
2
3
0
0
0
0
Not at all

Table 2. Number of Answers from the post-experiment questionnaire

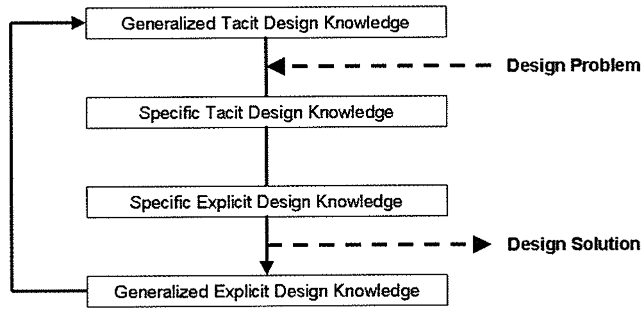


Figure 9. Theoretical Model Development

Overall, all respondents reported that they would consider using the software for sharing design knowledge in their next design studio. Student perceptions of chat were very positive. On a scale of 'Frustrating' to 'Very enjoyable,' all students answered with favorable ratings. Most of them reported that their experience with the software was very enjoyable and that the software is well-designed to support sharing of design knowledge (see Table 2). Students expressed that the chat sessions were very enjoyable, although some basic user interface issues had not yet been resolved (for example, screens were continuously refreshed and the chat thread could not be read). However, these data indicate that participants were very satisfied with the functionality of the software in terms of knowledge sharing.

Theoretical Model Development

The initial theoretical model was modified and extended as a theoretical model for design knowledge sharing process by formulating the research results (See Figure 9). Design knowledge sharing is initiated by applying 'generalized tacit design knowledge' to a specific design problem. When the students talked with their design critiques to acquire tacit design knowledge, the design critic's generalized tacit design knowledge may become 'specific tacit design knowledge' with the consideration of a specific design problem.

The students then convert specific tacit design knowledge into explicit formats, such as sketches, models, and drawings. Although those explicit expressions are often inadequate to fully articulate tacit design knowledge, it is a typical process of reflective practice in the design profession (Schon 1983). And then, the students and design critics update 'generalized explicit design knowledge', such as existing databases and codified information resources. Finally, the above experiences are accumulated as 'generalized tacit design knowledge' in the form of shared mental model or technical know-how (Nonaka and Tacheuchi 1995).

Conclusion

This paper addresses the needs of CMC strategies to share and reuse tacit design knowledge in a distributed design environment. Literature initially offered a theoretical background that the AEC industry could extend into a specific theoretical model for design knowledge sharing process. The case study then provided evidence that tacit design knowledge can be shared and reused by using chat-based CMC strategies.

In the experiment, the online chat was useful in sharing professional recommendations, intuitive expectations and past experiences. The participants easily identified well-defined design problems, thus enhancing conceptual design. Finally, the initial theoretical model was then extended as a theoretical model for design knowledge sharing process by formulating the research results.

The findings presented in this paper increase our level of understanding about the implications of tacit knowledge sharing. The results indicate that the synchronous chat sessions positively influenced design performance by virtue of tacit knowledge sharing. Student perceptions about the software were also very positive. All students would consider using the software for sharing design knowledge in their next design studio.

This research also suggests that tacit design knowledge may be confidently shared and reused through careful strategic implementation in a distributed design environment. Content analysis and demographic and attitudinal surveys of the participants suggest that enabling factors for sharing tacit design knowledge include knowledge sharing attitude, strong top-down management support, just-in-time expertise matching, CMC technologies support, and higher sense of cohesion. Strong management support and commitment from leadership can provide direction for knowledge sharing strategy.

Limitations

The analysis of some responses from the open-ended questions revealed needed improvements in the software development for more comprehensive design knowledge communications. Several reviewers pointed out that participation would have been greater and the measurable contribution could have been much greater, if the design project had begun using this interface in an earlier stage. The maturity of the project discussed in the chat sessions was the major barrier to this research. There are few suggestions on the time schedule for the chat sessions. They describe a successful use of chat but found it difficult to arrange chat schedules. They want to schedule more chat sessions with longer timeframes to form a more cohesive group. The students felt that the reviewers needed more time to understand the history and background of the projects.

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