SYNCHRONOUS CHAT FOR KNOWLEDGE SHARING IN A DISTRIBUTED DESIGN ENVIRONMENT

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Abstract: The knowledge of design experts, mostly tacit, holds tremendous value if made reusable for the right project at the right time. With emerging CMC (Computer-Mediated Communication) technologies, architectural practice has been transformed and faces new opportunities for capturing and reusing tacit design knowledge in a distributed design environment. This paper describes the impact of tacit design knowledge shared and captured by using online, interactive chat-based software. DKM (Dynamic Knowledge Map) has been developed to employ synchronous CMC to assist in the reuse of design experts' tacit knowledge in a distributed design environment. The software was tested it in a distributed design environment involving a high degree of expertise and consequent need for applying tacit knowledge. An instrumental case study approach was used for this research. Data were collected and analyzed using both qualitative and quantitative methods to enhance the validity of findings: content analysis, log files, simple statistics, and questionnaires. The results indicate that the interactive chat sessions and archives positively influenced the students' design performance by means of tacit knowledge sharing. This research also suggests that the importance of tacit design knowledge may be confidently enhanced through careful design in a distributed design environment.

Keywords: tacit design knowledge, Computer-Mediated Communication, Synchronous Chat, Knowledge Mapping

1. INTRODUCTION

Tacit knowledge is unwritten knowledge, such as expertise or professional insight, which is formed as a result of experience. Throughout the life-cycle of a project, architectural professionals rely heavily on their tacit knowledge for complicated design decisions [1]. For example, novice practitioners gain tacit knowledge through either direct experience or receiving instructions, and begin to extend the web of knowledge in the architectural domain. The tacit knowledge of architects has tremendous value if combined into one body of knowledge and shared with the right people at the right time.

Current architectural design process has been described as a multi-participatory distributed design environment [2]. With emerging Computer-Mediated Communication (CMC) technologies, architectural practice has been transformed and faces new opportunities for capturing and reusing tacit design knowledge in a distributed design environment. However, tacit knowledge sharing, although acknowledged as important to AEC firms, has not been confidently implemented through CMC. There are no accepted CMC strategies for managing tacit knowledge in the AEC industry. Therefore, there is a need for empirical research to fully exploit the potential of CMC technologies and enrich understanding of reusing experts' tacit knowledge in a distributed design environment.

This paper describes the impact of tacit design knowledge shared and captured by using online, interactive chat-based software. DKM (Dynamic Knowledge Map) has been developed to facilitate synchronous chat for assisting in the reuse of design experts' tacit knowledge in a distributed design environment. The software was tested in a distributed design environment involving a high degree of expertise and consequent need for applying tacit knowledge. Although statistical analyses have not been undertaken, quantitative and qualitative observations of the software use provided valid evidence to guide the direction of an appropriate use of tacit knowledge for architectural practitioners.

2. RELEVANT RESEARCH

Reviewing literature on knowledge sharing in a design studio [1], and Computer-Mediated Communication [2] elaborates the theoretical foundations and provide some preliminary answers to these unexploited 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?

A major limitation of current design studies is that little research has examined the potential of CMC to support the reuse of tacit design knowledge in a distributed design environment. In the field of CMC research, a few articles [3,4] 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 the access to tacit knowledge and might offer an organization a competitive advantage by improving its efficiency and expertise.

Several researchers in the field of architecture have emphasized the importance of tacit knowledge sharing in architectural design environments. For example, Schon [1] convincingly demonstrated that experts' tacit knowledge is a very important resource in the architectural profession. He explored 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. [5] stressed the importance of tacit knowledge in the design profession, especially in an educational sense. Cross and Cross [6] also conclude that the knowledge sharing process of design significantly influences the quality of design.

In the domain of architectural research, very few design research have been conducted concerning the effects of Computer-Mediated Communication on the architectural profession. Huang [2] studied the implications of collaborative media on design process by employing organizational economics theories. Kvan and Candy [7] conducted experiments to investigate the role of the computer system on the collaborative design communication over computer networks. In this study, chat-based software played a significant role in producing better design communications. However, their research did not explore the impact on the design artifact of reusing tacit design knowledge; rather, they focus on facilitating design communication.

3. RESEARCH QUESTIONS

The long-term goal of this research is to establish a theoretical foundation for clarifying the contribution of experts' tacit knowledge in the AEC industry and improving the documentation, access and reuse of tacit knowledge in distributed design organizations. The specific objectives and corresponding research questions of this research are to:

1) Observe the effect of tacit knowledge sharing, utilizing DKM, on the students' design artifacts.

   Research Question 1: How can DKM assist in capturing and sharing tacit design knowledge?

   Evidence
   - Working software that implements the proposed theory.
   - Opinion of software adequacy, collected through a questionnaire and students' feedback.

2) Do students who share tacit knowledge through synchronous chat apply the knowledge on their design artifacts?

Evidence
- Content analysis of dialogue transcripts, recorded through chat sessions.
- Analysis and criticism of design artifacts carrying the effects of tacit knowledge sharing.

4. METHODS

4.1. Research Design

An instrumental case study [8] approach was used in this research. Stake emphasizes the importance of multiple data sources in order to provide multiple perspectives. Data were collected and analyzed using both qualitative and quantitative methods to enhance the validity of findings: content analysis, log files, simple statistics, and questionnaires.

The focus of observation for this research is "tacit knowledge sharing operated by DKM in a design studio" as illustrated in Figure 1.

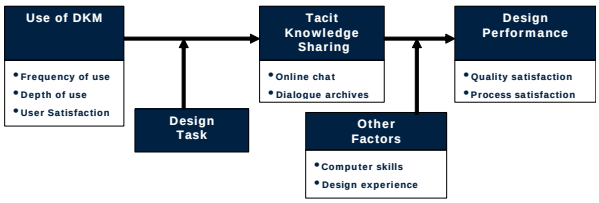


Figure 1. The Focus of Observation

4.2. Context

A graduate-level design studio at a southern university was selected; the studio conducted a design project on the long- term planning and design of facilities at the Peckerwood Garden in Hempstead, Texas. Three faculty members in the College of Architecture organized the design studio for graduate students from the Architecture, Landscape Architecture and Construction Science Departments.

DKM was introduced and integrated with traditional face-to-face design critiques, and all activities on DKM were tracked using log files. The computers used for the chat sessions are located at the university computer lab a setting that offers the same quality of using personal computers. The lab is very convenient to use and it is impossible to change any computer configurations or network settings.

4.3. Participants

Twelve graduate students, enrolled in an architectural

design studio at the university, were selected for this study. The participation of the research was voluntary and was unrelated to their class grade. The participants' average age was 21 years. They had one to two years of architectural design experience and all had previous experience on the same type of project. Twelve knowledgeable design experts, such as faculty members and architects who are technologically experienced, were selected and invited to be reviewers. They shared their tacit knowledge with students for the project by actively communicating using DKM. The researcher did not participate in chat sessions, except to answer technical questions and to help with software use.

4.4. DKM

DKM demonstrates new methods of sharing tacit design knowledge that include locating, selecting, and communicating with other architects who experienced a similar project. It is a synchronous CMC system with some functionality of asynchronous CMC added. The major functionality includes chat room, chat archive and expert search. The user of DKM searches for experts and facilitates communication with the experts. One of the major functionality provisions is to support the synchronous chat of design experts for sharing and reusing knowledge (See Figure 2).

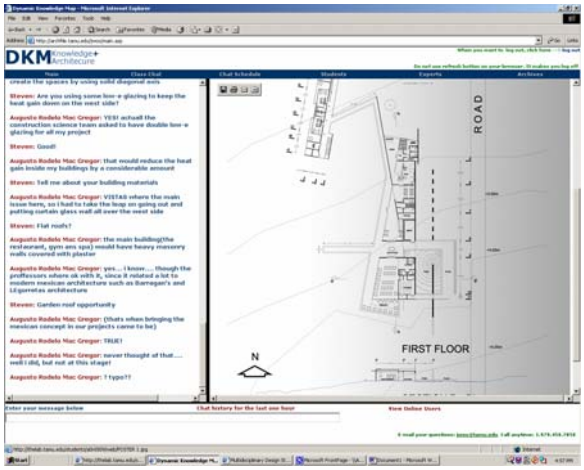


Figure 2. Screen shot of DKM

Architects shared their tacit knowledge by actively communicating with students using DKM. All dialogues were saved in a database as records of tacit knowledge sharing, and made accessible for non-participants to retrieve them for sharing the tacit knowledge conveyed in the dialogue. DKM incorporates a database for managing a chat archive to enable a knowledge seeker to gain advice from an expert. In addition, a grading function enables the system to develop a measure of usefulness or reliability of individual expertise on various design topics.

4.5. Data Collection

Two qualitative data were used for the content analysis: online chat transcripts and students' design artifacts. The online chat transcripts comprise messages between design professionals and groups of students. The actual chat content is analyzed to figure out how synchronous communication is used in a distributed design environment. The students' design artifacts comprise drawings and presentations that are produced in the design studio. Students' design artifacts were investigated to discover the improvement as a result of online chat conversations. Quantitative data mainly supplemented qualitative observational data to triangulate evidence to produce valid conclusions. Two questionnaires were distributed to the participating students to collect quantitative data. The online student questionnaire consisted of two pages, four of which were Likert type and semantic differential scale check boxes. Survey web location was sent by email message before couple of weeks before the last week of the semester.

The first survey was conducted on the first day of the experiment and collected the descriptive data about students' attitude of gathering design knowledge, previous design experience, tacit knowledge utilization and the use of CMC. The second survey was conducted on the last day of the design studio. This questionnaire is primarily designed to get feedback about software usability, ideas and satisfaction.

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

4.6. Data Analysis

Analysis of the chat transcript consisted of an iterative search for patterns that were meaningful to the design projects. The first step of content analysis began with reading the chat transcripts to investigate what people discussed in the chat sessions. Then, a code scheme were devised from themes emerged with repeated reading and past literature about theories of knowledge management and design studies. The entire messages in the chat transcripts were analyzed sentence-by-sentence and divided into small units by using three dimensions of categories; knowledge types, design activities and communication behaviors as shown at Figure 3. Gero and McNeill [9]'s coding scheme of design activities has been adopted as an initial reference in obtaining the major categorization of the chat messages in this study. Then, the coding scheme were extended and adjusted to cover the chat messages effectively.

Knowledge Type	Design Activities
Tacit Knowledge	Analyzing Problem
Explicit Knowledge	Proposing Solution
MISC.	Analyzing Solution
	Explicit Strategies

Figure 3. Coding Scheme

With this coding scheme, students' design artifacts were analyzed to discover the occurrences of tacit knowledge reuse and identified their role in students' design artifacts. This process will be qualitative and emergent to observe new phenomena freely [10]. However, the code scheme will let to answer following questions in a systematic way; what types of knowledge have been used to improve design artifacts? What kinds of design processes have been improved by using tacit knowledge? What aspects of design quality have been improved by using tacit knowledge?

5. FINDINGS

5.1. The role of DKM in tacit knowledge sharing

The analysis of log files and questionnaires is described in this chapter in order to answer the first research question, *"how DKM can assist in capturing and sharing experts' tacit knowledge?"* All students participated in the design studio completed and submitted a pre-experiment questionnaire. 7 students out of 12 students were involved in the chat sessions while 12 design reviewers logged in to the system for the chat sessions. They logged in at least three times, and stayed at least one hour, and produced at least 50 messages. 7 chat sessions were conducted during one month experimental period. Each chat session lasts approximately one hour. The participants produced 1,162 messages.

5.2. User Satisfaction

The data from questionnaires were used to evaluate the software and to consider how the software could be improved and implemented in a distributed design environment. Table 1 shows students' answers of their satisfactions on DKM. Significance statistics are not reported for the data due to the small sample size.

Overall, all students 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 claimed favorable ratings. Most of them reported that their experience with the software was very enjoyable and the software is well-designed to support sharing of design knowledge (See table 1). Students expressed that chat sessions were rated very enjoyable. Although some basic user interface issues had not yet been resolved (for example, screens are continuously refreshed so that chat thread cannot be read.). However, these data indicate that participants were very satisfied with the functionality of the software in terms of knowledge sharing. All respondents said that they would use this software in the next design studio.

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 1. Answers from the post-experiment questionnaire

5.3. The Impact on the Design Artifacts

The analysis of chat transcripts and design artifacts is described in this chapter in order to answer the first research question, *"Do students who share tacit knowledge through synchronous chat and apply the knowledge on their design artifacts?"* All chat messages were categorized by using the coding scheme mentioned in the above chapter. Table 1 shows the number of chat messages produced by the participants using the coding scheme. Figure 4 shows examples of chat messages of each category.

Message Category	MISC	Explicit Knowledge	Tacit Knowledge
Proposing Solution	19	10	79
Analyzing Solution	5	14	72
Analyzing Problem	17	5	13
Explicit Strategy	28	90	9
Non-design	414	12	11
Total	483	131	184

Table 2. Number of messages by each category.

Design artifacts and chat transcripts were analyzed to learn how the students apply the knowledge discussed in the chat sessions. During the chat sessions, the reviewers identified problems on the spacing of the building (See Figure 5). The reviewers' comments formed the most concrete

evidence of the problem. Quickly, the student identified particular problems that would influence their approach to developing a final design. A student produced a floor plan which is improved by the comments from the virtual reviewers, as shown in Figure 5.

Knowledge Type	Example
Tacit Knowledge	• It also helps me to create the spaces by using solid diagonal axis. • And keep in mind, that you can improve environmental friendliness one component at a time. Some things the owners demand, other things you can propose. Even green buildings are not ALL green.
Explicit Knowledge	• Is "Natural Capitalism" required reading there yet?
Other	• On slide 3, you may see the bigger first floor plan. • The walls are framing each space of my Meeting center.

Figure 4. Examples of chat messages

5.4. Comments from the participants

We also analyzed some responses from open-ended questions. Students were asked to make comments and recommendations about what should be improved in the software for more comprehensive design knowledge communications. These students' comments are valuable for improving the quality of DKM because these responses identify some weakness of current software. Students report some user interface problems and ideas that could be better in next time. The students' responses to this question included:

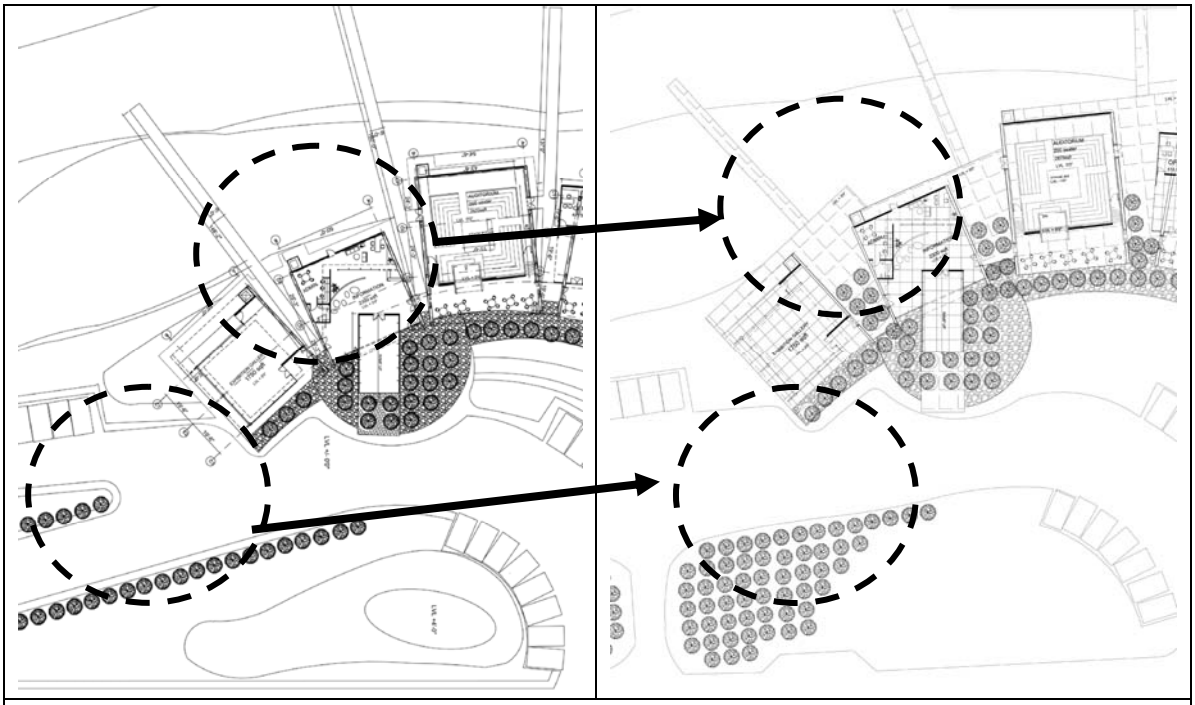
"I feel if the fact that the page is being refreshed continuously makes it difficult to read the chat conversation already taken place, although you have provided for the history option."

"If you could some how fix that I think it would be great. Also I know your intensions are different but if some sort of markup system could be provided it would be perfect. As architects always tend to draw...that's all the suggestions I have."

"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."

"Reviewers need to spend more time to catch the online discussion."

Comments are of the reviewer taken from emails. All reviewers were very positive about the potential



Reviewer 1: I feel that maybe the center of the arch needs to be referenced / celebrated....I mean the point across the parking
Reviewer 2: Your boxes are always open in one way or another.... therefore the edge of the walls are going to be VERY important....what is the material relationship between the face of the walls and the edge of the walls...color...material...
Reviewer 3: what is the spacing between buildings?
Reviewer 4: spacing at the narrowest point - that is closest to parking is too narrow..
Reviewer 5: maybe a big tree.... the Landscape Architects may like that....

Figure 5. An Example of a building design improved by the chat session

impact of the software in terms of its ability to share design knowledge. 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 the 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 finding it difficult to arrange chat schedules. They want to schedule more chat sessions with longer time frame:

"I think the time scheduled for this experience was too short. What I mean is, there was not enough time to continue the dialogue about the project further on and really see how it was developing."

"I suggest also that the design studio coordination programs from beforehand all the chat sessions so that the most participants would be present at that moment. That would increase the exchange of the ideas."

"Assign time or block segments within the chat room time for the students to outline their problems, potential solution, present questions, or identify new web pages for the experts/responders to review, prior to soliciting responses from the experts. This gives experts the opportunity to review the items before responding."

There are few comments regarding the possible improvement on the user interface:

"I also had some problems with the scales of the drawings, as it was difficult to distinguish the details. Would there be some possibility to make observations directly on the drawing?"

6. CONCLUSION

The findings of this research indicated that synchronous chat may be a tool that is used to help architects design reviews in a distributed design environment. This research suggested that the synchronous chat sessions were useful in sharing design tacit knowledge. Specifically, the participants indicated that the design programming and initial brain-storming phases are more suitable for the use of synchronous chat. The students also felt that synchronous chat have benefited to help problem solving on design issues and have improved the overall quality of the design solutions.

Participants have clear expectations that synchronous chat could be integrated with visual display, such as "mark-up systems", of the design projects and that it would significantly may improve architectural design process.

REFERENCES

[1] Schon, D., The *reflective practitioner: How professionals think in action*. New York: Basic Books. 1983.

[2] Huang, J., "Knowledge sharing and innovation in distributed design: implications of Internet-based media on design collaboration", *International Journal for Design Computing*, http://www.arch.usyd.edu.au/kcdc/journal/vol2/dcnet/sub5. 1999.

[3] Isaacs, E., Walendowski, A., Whittaker, S., Schiano, D., and Kamm, C., "The character, functions, and styles of instant messaging in the workplace", *Proceedings of the CSCW'02*, pp. 126-135, New Orleans, Louisiana. 2002.

[4] Ribak, A., Jacovi, M., and Soraka, V., "Ask before you search: pear support and community building with ReachOut", *Proceedings of the CSCW'02*. pp. 126-135. New Orleans, Louisiana, 2002.

[5] Suwa, M., Purcell, T., and Gero, J., "Macroscopic analysis of design processes based on a scheme for coding designers' cognitive actions", *Design studies*, Vol. 19, pp. 455-483, 1998.

[6] Cross, N., and Cross, A., "Observations of teamwork and social processes in design", *Design Studies*, Vol. 16, pp. 143-170, 1995.

[7] Kvan, T., and Candy, L. "Designing collaborative environments for strategic knowledge in design", *Knowledge-Based Systems*, Vol. 13(6), pp. 429-438, 2000.

[8] Stake, R., *The art of case study research.* Thousand Oaks: Sage Publications, 1995.

[9] Gero, J. S., and McNeill, T., "An Approach to the anlysis of Design Protocols", *Design Studies*, Vol. 17, pp. 21-61, 1998.

[10] Gall, M., Borg, W., and Gall, J., *Educational Research*. 6th ed. White Plains, N.Y.: Longman Publishers, 1996.