The Design of Shared Display Groupware for Supporting Interdisciplinary Collaborative Learning

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Abstract

Interdisciplinary learning has gained a lot of attention among educators for improving student learning. Through interdisciplinary learning can facilitate critical thinking and problem solving that cannot be easily achieved by individuals. Thus interdisciplinary learning is becoming a significant research topic in higher education. However, issues still exist among unequal participation, difficult integration of knowledge, communication, and terminology. This study focuses on two activities of interdisciplinary learning where 24 students participated. One interdisciplinary activity is first initiated without groupware to finish teamwork. As the activity concluded, communication patterns and conversations were then analyzed. Based on observing behavior of participants in collaborative interdisciplinary learning, a shared display groupware is designed for improving issues of interdisciplinary collaboration. In this study, the design of groupware and suggestions are proposed for improving interdisciplinary learning.

1. Introduction

Along with the rapid change in the world, the problems that humanity is facing are becoming complex. The problems we are facing may be the most complex problems that we have never encountered before, such as greenhouse effect, financial development, and so on. In other words, it could not be solved these complex questions only with single and specialized knowledge because the complex questions in society often involve knowledge in different domain. Thus, experts in various domain are required to collaborate to solve such problems [13]. The interdisciplinary team has various abilities and domain knowledge; thus, the collaboration of interdisciplinary team also benefits the development of creativity of the team [7]. In addition, Lattuca [11] indicated the importance of fostering the learning in interdisciplinary is helpful in improving students' abilities of critical thinking and solving problems. Therefore, interdisciplinary learning has become an important issue that students can solve problems with not only their professional knowledge but also the public knowledge to extend the existing knowledge and create new knowledge.

The issues about the collaboration in interdisciplinary were raised in the early Social Identity Theory and Self-categorization Theory. People tend to alien to those who have different backgrounds. This tendency causes the phenomena that the actions of interchanging information between members in different domain in an interdisciplinary team [16]. However, this causes some members could not proactively attend the activities in the team. The main obstacle is the differentiation of personal background in knowledge which cannot be properly interchanged and resulted into hardly have a common way to solve problems. This cause the identifications of members of an interdisciplinary team [6]. Therefore, the interdisciplinary collaborative team must establish their common points so as to facilitate the discussions [4][10]. For example, Andersson and Kalman [1] indicated the important factor to establish consensuses is that people can specifically present what they think and what they understand. However, due to the differences between the cultures in different domain on thinking and working, the difference in terminology is the most common problem in the collaborations between different domain. Such situation has obstructed the establishment of consensus in an interdisciplinary team [3]. Therefore, in order to facilitate the collaborations of interdisciplinary teams, it is most important to improve the mutual understandings on the knowledge between different domain in an effective communication way.

Recent years, many technologies have been gradually developed to assist people to collaborate for learning. For example, Liu et al. [12] demonstrated a classroom provided with shared displays to assist collaborative learning. In addition, groupware is also helpful for collaborative learning because it can allow the team develop common understanding of knowledge. Through the mechanism that simultaneously update and share knowledge, students can instantly interact with colleagues and construct new understanding of knowledge. Many interdisciplinary

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courses also utilize groupware to assist the collaborative learning [9][11]. However, the way how groupware demonstrates group discussion may affect group work and performance. For example, Nussbaum et al. [15] show that the discussing systems with concept mapping tools are convenient to link all comments from members and make the team reach consensus easier. Therefore, the purpose of this study is to assist the exchange and integration of knowledge by groupware combined with the conceptual graphics tool and explore the influence to students when the interdisciplinary collaborations are carried out with the shared display groupware (SDG).

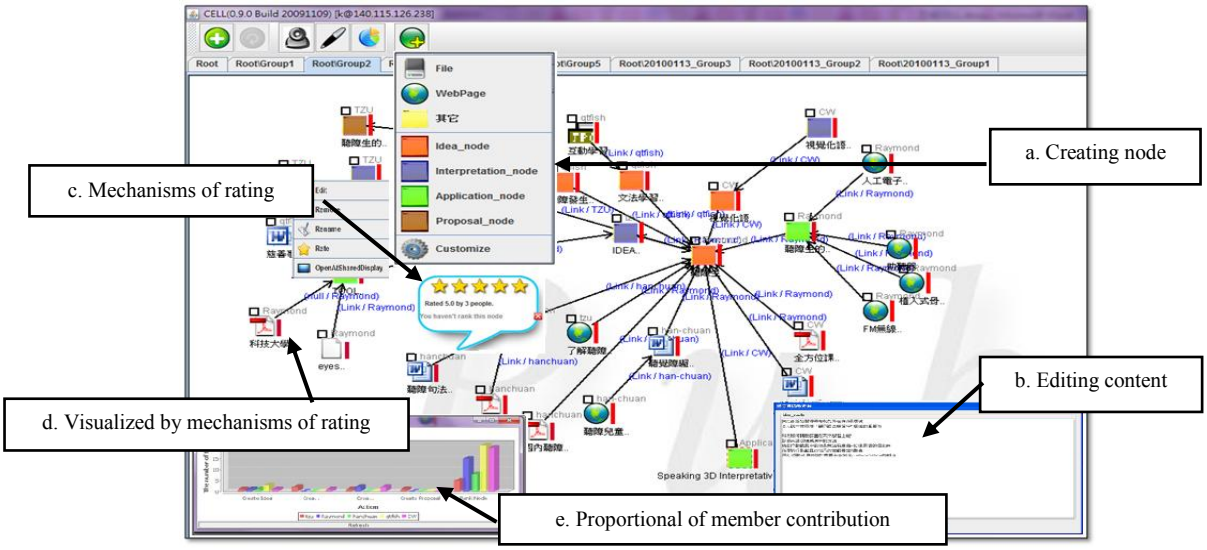

Figure 1. The CELL Groupware Scheme

2. The design of shared display groupware

This study proposed a shared display groupware to assist students within an interdisciplinary collaborative team in exchanging and sharing the ideas so that those students could join together to reflect upon the information they had found on the Web. In other words, this study developed a groupware which can facilitate the contributing, exchanging and linking for learning (CELL). Figure 1 shows the snapshot of CELL groupware. There is a public space for supporting interdisciplinary collaborative activities. The team members can utilize the public space contributing, exchanging, commenting, and linking resources to construct a common solution toward a interdisciplinary collaborative activity. In addition, the mechanisms of conceptual mind tools were integrated into the CELL in order to facilitate the observation of teammates' conceptual thinking and further improve the quality of argumentation among teammates in collaborative learning environments.

2.1 CELL facilitate personal opinion expression

A student could express the idea, interpretation, application, and proposal of knowledge by creating nodes (Figure 1.a). In order to enhance the distinguishing of each type of expression, each type of node is presented in different colors. The design of four types of nodes is to assist the student in different domains to clarify their own ideas to facilitate expressing opinions and discussing. Each node provides the file-uploading function for exchanging files. After the nodes are established, students can double-click the node to conduct editing or viewing the contents in the nodes (Figure 1.b). It was hoped that the team members can have understanding in terms of terminology through verbal, textual, graphic, and video channels to facilitate information exchange among them. CELL groupware can also help the team members to integrate multiple opinions through the link function, so that the team members can improve the integration of the information in the team by establishing group conceptual mind map.

2.2 CELL improve personal attention and participation

The team members can see the ideas of other members while these ideas were uploaded to the public space. It is very important to share ideas among teammates during the interdisciplinary collaborative learning, so that the information exchange can be improved and avoided the unevenly participation. In addition, CELL allows teammates rate all nodes in the public space by the rating mechanism (Figure 1.c). Meanwhile, a red bar chart on the right side of each node demonstrates the scores that teammates rated (Figure 1.d). Through the scoring mechanism of conceptual mind tools, the members can

clearly understand the assessment of each node. It hoped activate the attention of teammates as well as encourage members to contribute their ideas within the interdisciplinary learning activities. Additionally, CELL reveals the proportional chart of each member contribution (Figure 1.e). In other words, the contributions of members can be shown timely during the activity. It helps the team members cannot only realize the nodes issued by which members but also handle the progresses of discussions by observing the numbers of different types of nodes.

3. Research methods

An experiment was performed to examine the effects of applying CELL in interdisciplinary collaborative activity.

3.1 Participants and interdisciplinary collaborative activity

The subjects of this study were 24 graduate students enrolled in the course of "Creativity Assistance Tool" at an university in northern Taiwan. There were 14 participants with the background of information technology, while the others were with the background of learning and teaching. All the participants were divided into five teams in which the members of a team ranged from four to five. Each team involved in at last two members came from the same background.

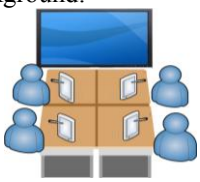

Figure 2. Scenario of 1st learning activity

Figure 3. Scenario of 2nd learning activity

In order to examine the effects of applying CELL in interdisciplinary collaborative activity, two interdisciplinary learning activities were conducted during the period of learning course. The first time of interdisciplinary collaborative activity, each participant owned a laptop computer. Besides, one of members' laptop computer was connected to a shared display to facilitate the co-work (Figure 2). The learning activity lasted for three weeks and each week took one hour. During the learning activity, the participants could search data through the Internet, share their ideas and search results, discuss and integrate their ideas to finish group work. And, they were free to choose the integrating tools that they are used to, such as Office, Google docs, and so on. At the end of the learning activity, each team should propose an interdisciplinary proposal. The procedure of second time of interdisciplinary learning activity is similar with the first one except that each team was equipped with the CELL (Figure 3). Therefore, each team could construct and integrate the learning works through the CELL.

3.2 Data collection and analysis

The research data was collected from the recording of learning activity. All collaborative activities and discussions of participants were videotaped by five video cameras on the ceiling of classroom for subsequent analysis. In order to obtain a better understanding of the participants' collaboration behaviors, this study also screen captured the shared display screen while they participated in the interdisciplinary collaborative activity. In order to clarify the effects of applying CELL in the interdisciplinary learning, this study conducted the qualitative analysis to illuminate the interaction and communication among teammates. The qualitative analysis would be based on the communication pattern analysis and content analysis of dialogue which were illustrated more detail as following.

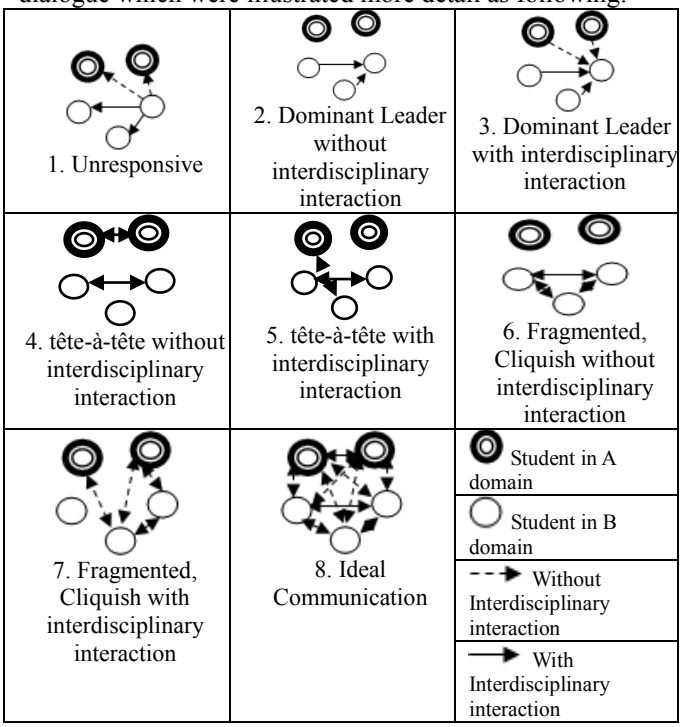

Figure 4. The category of communication patterns

3.2.1 Communication pattern analysis. Milson [14] indicated that some communication patterns would appear in a team and could be applied for evaluating communication performance in the team. However, not all communication patterns are categorized by Milson. Chen, Wang, and Ou [5] further indicated the communications among the teams are not limited in these patterns. Therefore, this study adopted Milson's communication patterns as the basic categorization to evaluate the interdisciplinary collaboration.

According to the contexts of verbal dialogues and observing the actions in the videos in the activities, the length of each

dialogue is determined (when there is no direct relationship between the previous topic and the next topic). This study selected eight communication patterns as shown in Figure 4 to analyze the differences and performance in terms of the verbal interactions within a team during the interdisciplinary collaborative activities, i.e. 1)Unresponsive, 2)Dominant leader without interdisciplinary interaction, 3)Dominant leader with interdisciplinary interaction, 4)tête-à-tête without interdisciplinary interaction, 5)tête-à-tête with interdisciplinary interaction, 6)Fragmented, cliquish without interdisciplinary interaction, 7)Fragmented, cliquish with interdisciplinary interaction, and 8)Ideal communication.

3.2.2 Content analysis of dialogue. Fink [8] proposed significant learning theory in the course of interdisciplinary, which includes foundational knowledge, application, integration, human dimension, caring, and learning how to learn. He designed the course and evaluated the learning performance of students for interdisciplinary learning. Thus, this study analyzed the conversations related to information exchanges and integrations in the team in accordance with 3 of 6 learning aspects raised by Fink, such as foundational knowledge, application, and integration. In addition, question and team development that usually appear in the team discussions are also applied to analyze the conversations. The rest shorter dialogues are defined as simple responses that will be compiled for statistics additionally. The definitions of the five dialogue types are following: 1)Foundational knowledge indicates the ideas triggered by the personal existing knowledge. 2)Application is to explain and describe ideas by oneself or others, and give examples for applications. 3)Integration indicates relationships established through coordinating learned contents, ideas, people, and conditions. 4)Question indicates the questions that triggered discussions. 5)Team development is about how the team members decide to proceed with discussions, or which way should be used to illustrate the reports. There is no direct relationship in terms of discussed contents, but this would affect the smooth of discussions.

3.2.3 Data analysis. Therefore, the interaction frequency of each team was clarified by analyzing the dialogue based on the communication patterns. Besides, to observe the causes of these communication patterns and the effects in facilitating integration of interdisciplinary team and the terminology, the dialogue types are also analyzed in this study so as to show which key interactions in dialogues occurred. The communication patterns and dialogue types of all dialogues are cross-analyzed. After the experiment was completed, the researcher converted all dialogues in videos and the information on the shared display to texts. Two researchers independently categorized the dialogue types. Within the categorizing processes, only the dialogue marked under the same category by both researchers would be identified as the same analytical result. Otherwise, the dialogue would be classified as unidentical result. The unidentical results would be confirmed by both researchers after they discuss with each other. The Non-CELL and CELL would be denoted as the first and second time interdisciplinary collaborative activities.

4. Results and discussion

4.1 The influences of communication patterns

In order to examine the effects of applying CELL in interdisciplinary collaborative learning, the number of communication patterns was counted for each Non-CELL and CELL activities. Table 1 shows the number of communication patterns in Non-CELL and CELL activities. The total number of communication patterns of Non-CELL is higher than the CELL (775:525). It is found that the number of *Dominant Leader with interdisciplinary interaction* is highest (231) under the Non-CELL activities. However, the discussions were often dominated by one participant. *Fragmented communications with interdisciplinary interaction* (210) also reveals a high frequency, but ideal communications (48) has only a few under the Non-CELL activities. It is often that some participants did not tend to express their opinions during collaboration. In the interviews after the experiments, it was found these participants thought their opinions were usually ignored; thus, they were not willing to express their opinions.

Table 1. Number of communication patterns in Non-CELL and CELL activities (Unit: number of dialogue)

Communication Pattern	Non-CELL	CELL
Unresponsive	60	41
Dominant Leader without interdisciplinary interaction	101	38
Dominant Leader with interdisciplinary interaction	231	111
tête-à-tête without interdisciplinary interaction	48	37
tête-à-tête with interdisciplinary interaction	60	64
Fragmented, Cliquish without interdisciplinary interaction	17	10
Fragmented, Cliquish with interdisciplinary interaction	210	156
Ideal Communication	48	68
Total	775	525

To compare the communication effects of Non-CELL and CELL activities, the frequency of *Dominant Leader without interdisciplinary interaction* decreased (101→38), and the frequency of *Dominant Leader with interdisciplinary interaction* also decreased (231→111). Thus, it reveals the phenomenon of discussions dominating

by one person decreased after applying CELL in the interdisciplinary activity. In addition, the frequency of ideal communication pattern increased (48→68). As for the fragmented communication patterns and the tête-à-tête communication patterns (including with and without interdisciplinary interaction) were decreased (227→166). Therefore, CELL groupware can improve the team collaboration from fragmented discussions to consistent discussions within a team.

Comparing the number of utterances between the Non-CELL and CELL activities, the total number decreases (3314→2540) (Table 2). Such phenomenon is inferred that some ideas are shown by CELL that instead of verbal communication. Moreover, the average number of utterances contained in communication patterns increases (4.28→4.84) as well as the average number of interdisciplinary dialogue in each communication increases (1.77→2.10). This phenomenon means that the participants paid more focus on the discussion topic, and they can develop their teamwork toward the interdisciplinary collaboration.

Table 2. The number of interdisciplinary dialogue in Non-CELL and CELL activities (Unit: number of utterances)

	Foundational knowledge	Application	Integration	Question	Team development	Simple response	Total
Non-CELL	325	546	142	166	192	1943	3314
CELL	233	649	144	144	104	1436	2540

4.2 The effect of participants' dialogue content

The integrating actions are very important in the discussions of interdisciplinary collaboration activity [2]. It can show the processes that the students solve the problems with the knowledge they have each other. Considering the integration action of interdisciplinary dialogue between Non-CELL and CELL, the number of Non-CELL is less than the CELL (142:144) as shown in Table 2. By observing the video of the activity, it was found that the team members always forgot what they discussed before; therefore, they needed to take a lot of time to retrieve the prior data to clarify their ideas and concepts. In other words, during the stage of Non-CELL activity, it is not easy to carry out the discussions related to integration. Additionally, the participants often utilized software, such as Google Document, Office, and so on, to integrate the data of discussions. However, these tools are unable to denote the contributions of individual team members, so that it is difficult to link multiple ideas in the collaborative processes. On the other hand, during the stage of CELL activity, the dialogues related to integration action increase from 10.4%(142/1371) to 13%(144/1104). The number of 1371 was calculated from the total number of utterances of the Non-CELL deducts the number of simple response (3314 minus 1943, Table 2). The calculation of 1104 came from the number of CELL activity (2540 minus 1436, Table 2). It inferred that the public space of CELL allows the team members to save data and ideas contributed from every one. Moreover, the conceptual mind tools could not only support the teammates to link the ideas but also demonstrate the relationship among these ideas. Therefore, it is easy to facilitate ideas integration during interdisciplinary collaboration.

4.3 The efficacy of different domain learners

To achieve a better understanding of the efficacy of CELL to facilitate the different domain learners, this study further analyzed the dialogue content based on the communication patterns among the domain areas of information technology, and learning and teaching. The results were shown in Table 3. It was found that the communication patterns under Non-CELL activities in a dominated with interdisciplinary interaction usually proceeded with the sharing dialogues of foundational knowledge type which is 71. By observing the videos of the activities, it was found the foundational knowledge raised by different territories was always ignored or denied because of misunderstanding each other. When the activities were carried out with CELL groupware, the utterances related to foundational knowledge in the dominated with interdisciplinary interaction are reduced (71→28). On the contrary, the utterances related to foundational knowledge in the ideal communication are increased (36→52). This means the team members tend to discuss and exchange their knowledge instead of just receiving knowledge form one member. By observing the videos of the activities, it was also found the node rating function provided by CELL groupware makes the nodes attract the attentions of members, and this further provide the opportunities that team members discuss their idea with each other.

It was found the questions raised by the participants from the learning and teaching domain are more than the information technology domain under Non-CELL activities in Table 3 (110 and 56, respectively). By observing the videos of the activities, it was found that the team members are rather difficult to reach consistent consensuses in verbal interaction due to the terminology in different domains. However, when they collaborated with CELL groupware, the number of questions raised by participants from learning and teaching domain is reduced (110→85). The number of utterances related to application by the participants from the learning and teaching domain is higher than the information technology domain (227 and 252, respectively). By observing the videos of the activities, it was found that the participants from the learning and teaching domain were unable to extend the application with the foundational

knowledge of information technology under the Non-CELL activities. However, by using CELL, they can easily understood the knowledge from information technology domain and also discuss the application of technology. Such phenomenon demonstrates that the problem of terminology between different domains was improved.

Table 3. The Comparison of Interdisciplinary Dialogue between two domains (Unit: number of utterances)

Domains	Foundational knowledge	Application	Integration	Question	Team development	Total
Non-CELL						
Information technology	162	248	78	110	121	1819
Learning and teaching	163	298	64	56	71	1495
CELL						
Information technology	126	252	67	85	47	1354
Learning and teaching	107	227	77	59	57	1186

5. Conclusion and implications

This study proposes the CELL groupware to enhance interdisciplinary collaboration. The finding demonstrated that CELL is helpful in promoting information exchange, enhancing group communication and understanding of the learning tasks, and deepening group discussions via the public space. Additionally, CELL equips with the mechanisms to view team members' contributions as well as to assess the contribution. Therefore, the quality of the nodes could be visualized by the rating on the nodes and the team members can pay more attention on the idea raised by others. Moreover, CELL provides linking function that members can organize their thinking while they propose their ideas to clarify the foundational knowledge and application through establishing a conceptual mind tools. This study found the linking function can improve the efficiency of the integration in the discussing processes and allow the team members to start idea integration in early stage. On the other hand, through the information simultaneously showed on the CELL, students can explain the terminology in verbal, textual, graphic, video ways, which help students to build a common consensus during collaboration. Therefore, team members can perform better communication patterns in interdisciplinary collaboration.

Further work needs to be undertaken with a larger sample to provide additional evidence. Future studies should apply in students with more different knowledge levels to reveal how the CELL can provide assistance to a wider range of interdisciplinary collaborative activities. These new findings can also be provided to the designers of learning systems to aid them in improving their current design of groupware and curriculum design in the classroom.

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