Evaluating system-based strategies for managing conflict in collaborative concept mapping

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Abstract This study examined the influence of various conflict management mechanisms embedded into computer-supported collaborative concept mapping systems on the behaviour and learning of elementary students. Four conflict management mechanisms were compared: an *assign* design, in which the mapping control was designated to a particular group member; a *rotate* design, in which the mapping control was rotated among the group members; a *give* design, in which the child with mapping control could relinquish control to another group member; and an *open* design, in which every group member simultaneously had mapping control. Ninety-six fifth and sixth grade Taiwanese students participated in this study. They were arranged into *assign*, *rotate*, *give*, or *open* three-member groups to generate collaboratively shared concept maps. Student interactions, attitudes, and achievement were analysed. The results suggest that each conflict management mechanism has a different effect on the elementary students.

Keywords collaboration, concept mapping, conflict control management, empirical, groupware, primary

Background

Concept mapping is a technique developed by Prof. Joseph D. Novak at Cornell University in the 1960s for representing knowledge in a graph. The graph is composed of nodes and links. The nodes represent concepts, while the links represent the relationships between the concepts (Novak & Gowin 1984). Concept mapping is now widely used in scientific learning (e.g. Schmid & Telaro 1990), instructional planning (e.g. Edmondson 1995), and concept evaluation (e.g. Williams 1998). Many researchers have agreed that concept mapping, which includes integrating new related concepts, establishing new links or re-arranging existing concepts and links, can assist in bringing about meaningful learning (Heinze-Fry & Novak 1990). Horton *et al*. (1993) also found that concept mapping generally had a positive effect on both knowledge attainment and attitude in a meta-analysis of 19 studies.

Concept mapping was traditionally carried out by hand using a pen or pencil on paper. Making a paper-and-pencil concept map usually required a significant amount of effort. Any deletions, additions, or changes to the map could be very frustrating. This would distract students from concentrating on their knowledge and would diminish the learning effects (Huang 1995). With the advancement and popularization of the personal computer, several computer applications were developed to support concept mapping, such as Inspiration (http://www.inspiration.com/), SemNet Software (http://www.biologylessons.sdsu.edu/about/semnetdown.html), and Axon Idea Processor (http://web.singnet.com.sg/~axon2000/). These computer

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applications make generating, modifying, or manipulating a concept map relatively easy (Anderson-Inman & Horney 1996/1997). Students can then focus their attention on understanding the concepts and interrelationships instead of scribbling and erasing map parts.

Concept mapping is often implemented collaboratively. Students are arranged into three to five person groups to generate shared concept maps. Studies have proven that students who collaboratively complete shared tasks tend to develop a greater comprehension of the content and skills they are studying (e.g. Slavin 1991; Johnson *et al*. 1993). Although not many studies have investigated the effects of collaborative concept mapping, most of them have found that collaborative concept mapping can lead to effective discussions concerning the concepts and thus enhance learning (e.g. Roth & Roychoudhury 1993; Roth 1994). With the advent of ubiquitous computer networking, such collaborative concept mapping can be expanded among distributed students. Students might easily connect, exchange ideas, and generate joint concept maps with others regardless of their respective locations or the time (Chung *et al*. 1997).

However, a specific network application is required to allow separate individuals to participate collaboratively in a concept mapping activity. Because collaborators cannot converse directly face to face, the application must provide functions for mutual communication. Currently, technology has made this feasible and can support text, audio, and video messages. In addition, the application must support collaborators jointly generating and viewing shared concept maps, like shared text editors, collaborative design environments, etc. Support for such a synchronous collaboration by separated students is a challenge. Once every collaborator can directly manipulate concept and link objects in a common workspace at the same time, the conflict problem in application program is very likely to arise. However, some collaborative systems for general purposes (not specifically for generating concept maps) imposed no particular control, i.e. *open* any partner to manipulate shared artefact objects. As Avouris *et al*. (2003) pointed out, this design would create co-ordination problems, with the participants ending up writing one on top of the other and cancelling one another's actions. To provide protection, implicit group social protocols must be established by the participants. This relies on people's natural abilities to anticipate actions, mediate events, and resolve conflicting interactions. Although social protocols will generally work, Baker (2002, p. 49) noticed that this approach is not always preferable. Other systems thus propose building floor control mechanisms (technical controls) into architectures. Existent collaborative concept mapping software often adopted such a scheme to prevent or manage concurrent conflicts. The mechanisms involve the arrangement of a controller/a co-ordinator to impose explicit co-ordination (Morris *et al*. 1992; Dix *et al*. 1998; Avouris *et al*. 2003). That is, using locking to restrict the mapping floor to a co-ordinator member at a given time. Only that member could manipulate the concept map at that time. The other group members could utilize text-based or voice communication facilities to send advice, suggest alternative actions, comment on their partner's actions, etc.

Various floor control protocols exist, such as the floor being explicitly requested and relinquished or the floor being taken in turns. In Representation 2.0 by Komis *et al*. (2002), ModellingSpace by Avouris *et al*. (2003), and ModelsCreator 3.0 by Fidas *et al*. (2002), the mapping control could be passed to a partner at any point during collaboration through a control request/control accept/control reject protocol. The current control holder could decide whom and when to accept a control request and *give* over control. Experiments demonstrated that this design improved reasoning and negotiating during control requests (Fidas *et al*. 2002; Komis *et al*. 2002). However, this design could create deadlocks in cases when one partner cannot proceed with accomplishing the shared concept map and at the same time refuses to pass the mapping right over to another partner (Fidas *et al*. 2001). Avouris *et al*. reported that such situations did occur during related experiments. To overcome this deficiency, the control holder could be compelled to release the floor through a mechanism that released control if the current control holder was inactive for more than a certain time. The floor would then be automatically given to the first requesting partner. However, if no one requested the floor, deadlocks would arise again. In the Networked Concept Mapper developed by Chung *et al*. (1997), the mapping control was automatically taken from the control holder and automatically given to another partner every 12 min. The mapping control was *rotated* among the group members. Chung *et al*. claimed that such an approach allowed each member equal control over the shared concept map. However, through this protocol any later controller could destroy parts of the shared map developed by former controllers. Chiu *et al*. (2000) modified the *rotate* design. The mapping control was *assigned* to a particular member during a collaborative concept mapping activity. The remaining members could not directly manipulate the shared map. This protocol conforms to the idea of prescribing roles, e.g. arranging an executor for concept mapping and a reflector to observe and comment. This can be an effective design based on the generally accepted argument that constructive collaboration would take place if peers take on appropriate roles (O'Malley, 1987; Kumar, 1996). In spite of this, a drawback may exist. When non-control-holders propose any modifications and make suggestions to the controller, such collaboration usually requires a long dialogue that can create ambiguities.

To date, no convincing evidence exists for a superior conflict management mechanism for a collaborative concept mapping system that maximizes group learning. Because the system features may modify interactions among learners and an inadequate design could lead to inadequate effects, it is necessary to determine how various conflict management mechanisms influence student learning. This study was therefore designed to investigate if the conflict management mechanism embedded in a collaborative concept mapping system would create a difference in student performance, and which approach would result in better student learning. This study focused on elementary school students. The evaluated conflict management mechanisms included *assign*, *rotate*, *give*, and *open* protocols, which are the most common protocols available in collaborative concept mapping systems. To determine the differences, this study evaluated student performance and attitude. Because how groups interact could provide a good understanding of how learning is affected, the types of interactions were also assessed.

Method

An experiment was set up to determine whether achievement, attitude, and interaction differed for elementary students during/after collaborative concept mapping activities under *assign*, *rotate*, *give*, and *open* situations. The independent variable was the conflict management mechanism designed into a Web-based collaborative concept mapping system. The dependent variables were student achievement, attitude, and interaction.

Participants

This study involved 96 students in Southern Taiwan. Twenty-four fifth-graders and 48 sixth-graders were from one school and 24 sixth-graders were from another school. These participants were about average compared with students in the same grades with respect to academic performance. They had about 2 years of formal education in computer basics and applications. They were able to use a word processing program, a painter program, and an Internet browser.

Collaborative concept mapping system

The system supported geographically dispersed users in a group designed to interact with one another and generate a joint concept map. This system was Web-based so that the users could use a typical Web browser to co-map. A centralized (client–server) architecture was adopted instead of a replicated architecture because of its simplicity at handling concurrency due to co-mapping (Greenberg 1990; Patterson *et al*. 1990).

This system included six main components: mapping, collaboration, awareness, communication, tracing, and management. Figure 1 shows the user interface. The mapping component provided functions to generate, manipulate, and modify a concept map. Concept nodes or relation links could be added to or deleted via menu selections, and could be arbitrarily moved and positioned by towing the mouse. The collaboration component supported collaborators co-producing a shared concept map in the following modes:

- *Assign*: The mapping control was fixed to one member of a group during a collaborative concept mapping activity. The other members could not take control.
- *Rotate*: The first member of a group to log in took mapping control. Every three min, the mapping control was automatically rotated to the next present member.

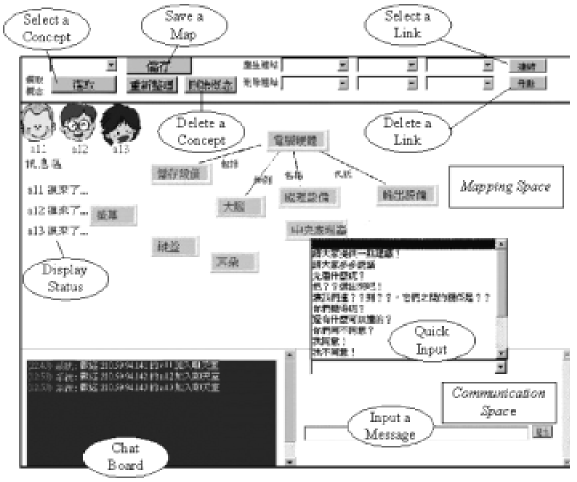

Fig. 1 User interface for the Web-based collaborative concept mapping system.

- *Give*: The first member of a group to log in took mapping control. However, the current controller decided when and to which member control was relinquished.
- *Open*: All the members in a group could concurrently manipulate the nodes and link objects of a shared concept map. Lock-based concurrent control was adopted in this system because many collaborative applications use this scheme to prevent inconsistency from co-updates (Berlage & Genau 1993).

Regardless of who had mapping control in a group, every member's computer screen would be updated accordingly. The group members could view the same map on their respective screens (each member sees the same view modulo some communication delay). The awareness component helped each member in a group to maintain up-to-the-moment awareness of one another concerning member absence and activities. The communication component supported text-based synchronous dialogue. Networked group members could type to discuss and negotiate during shared concept map production. A quick-input mechanism (Chung *et al.* 1997) was included in the program to help with typing speed. Students could use predetermined frequently used messages (such as '*I suggest our selecting X.*' '*Do you all agree?*' '*I agree.*', etc.) to convey their ideas (with little modification). The tracing component traced the entire mapping process and conversations within each group and recorded the data into the system database. Through the management component, an approved teacher could launch, modify, delete, and manage a collaborative concept mapping activity.

Experimental treatments

The experiment was run in the computer laboratories of the participants' schools. Both laboratories had IBM-compatible computers. An NT server with a Web-based collaborative concept mapping system installed was brought into the laboratories to support this experiment.

Prior to treatments

The participants were introduced to the concept mapping method to prepare them for the study treatments. This took 80 min, including practice on individual and collaborative paper-and-pencil concept maps about *the human body*. The participants were given 40 min to connect to a Web-based chat room to practice typing to communicate to give them computer-mediated communication experience. The participants were then introduced to the Web-based collaborative concept mapping system. Learning how to use the system to generate collaboratively a group concept map took another 40 min.

Formal treatments

The participants were randomly divided into four situations: *assign*, *rotate*, *give*, and *open* situations. In each situation, the participants were arbitrarily organized into three member groups. Eight groups were formed for each situation. Each group was asked to generate collaboratively concept maps. In the *assign* situation, one member always had mapping control and the other members did not. In the *rotate* situation, members followed one another in three-minute rotations for mapping control. In the *give* situation, one member with mapping control could give it to another member of his choice. In the *open* situation, all members had mapping control at the same time. During group concept map generation, three research assistants were assigned to monitor and restrict the participants from having face-to-face conversations or viewing another's screen.

Concept mapping tasks

The concept mapping tasks the participants were asked to accomplish were on the topics of *hereditary* *features of humans*, *atmospheric layers of the Earth*, and *the food chain*. Sixteen concept nodes with five relation links, thirteen concept nodes with seven relation links, and twenty concept nodes with eight relation links were predefined in the system for the participants to include in their concept maps. During each task, the participants were supplied with a page of topic-related information for reference. The first two tasks lasted 40 min. The third task lasted 60 min. The time intervals were determined using a trial on six fifth- and sixth-grade students.

Measurements

Achievement

Participant achievement was measured using (a) in-treatment group concept maps, and (b) subsequent individual concept maps 2 weeks later. Three joint concept maps were generated by each group in the experimental treatments. All participants in a group received the same score for the group concept maps. Two weeks after the treatments, each participant was required to complete three concept maps on the same topics used in the treatments. These concept maps reflected the knowledge retained by the individual participant and were scored individually.

Three elementary natural science teachers worked together to score the group and individual concept maps. The scoring scheme was modified from a typical algorithm proposed by Novak and Gowin (1984) and consisted of the following rules: (a) every valid proposition (concept-link-concept) scored 1 point; (b) every valid level of hierarchy scored 5 points, and (c) each cross link scored 10 points if significant, or 1 point if not significant.

Each participant received three scores from the group concept maps and three scores from the individual concept maps. To eliminate the variability influence in the original scores caused by unequal difficulty among mapping topics and content, *T*-scores were computed (Cross 1995) for each map and summed up for the in-treatment group maps and the subsequent individual maps.

Attitude

The attitude toward collaborative concept mapping (ACCM) was designed to measure student attitudes and perceptions towards concept mapping and collaborative concept mapping. This instrument consisted of 18 Likert-scale statements, 7 for concept mapping (e.g. concept mapping can help me to understand the relationships among concepts.), and 11 for collaborative concept mapping (e.g. While collaboratively constructing a joint concept map, we can clear up many confusing matters together.). Students can indicate their feelings by selecting one of five choices from *agree strongly* to *disagree strongly*. Three judges evaluated the items for construct validity and clarity. The reliability of this instrument was established using a pilot test with 119 fifth- and sixth-grade students. Cronbach's alpha estimates of reliability for the two subscales were 0.80 and 0.83 in the pilot test, and 0.82 and 0.84 in the formal study.

Interaction

The dialogues from the four treatment situations (*assign*, *rotate*, *give*, and *open*) were coded and analysed. Because the amount and time used to explain correlate highly with the amount learned (Lamm & Tromsdorff 1973; Johnson & Johnson 1992), dialogues related to knowledge construction covered by the concept mapping topics were counted (such as '*What's the relationship between gene and human features?*', '*It should be the atmosphere contains troposphere.*' or '*Place consumer below producer.*').

Data analyses

One-way ANOVA was used to determine if a significance existed among the students in the *assign*, *rotate*, *give*, and *open* situations in terms of the scores for the in-treatment concept maps and the subsequent concept maps, attitudes toward concept mapping and collaborative concept mapping, and the amount of knowledge-related dialogues. A two-tailed α value of 0.05 was used in all cases to determine the statistical significance. If any significant difference existed, a post-hoc comparison test, the Scheffé Test, was used to test the difference between each pair of situations.

Results

Achievement

Table 1 summarizes the means and standard deviations for student performance under the *assign*, *rotate*,

Table 1. Means and standard deviations (SD) on in-treatment and subsequent *T*-scores.

	In-treatment			Subsequent		
	n	*Mean*	SD	*n*	*Mean*	SD
Assign	24	164.17	22.68	24	160.26	26.30
Rotate	24	132.88	24.34	24	138.80	22.05
Give	24	156.93	22.73	24	146.76	24.25
Open	24	154.33	16.42	24	150.82	21.38

give, and *open* situations in terms of the scores from the in-treatment concept maps and the scores from the subsequent concept maps. The ANOVA results for the in-treatment scores revealed a significant difference among the four situations, $F_{3,\ 92} = 9.191$, $P < 0.001$. The Scheffé test indicated that the in-treatment scores for the *assign*, *give*, and *open* situations were significantly higher than the *rotate* situation ($P = (< 0.001)$, 0.003, 0.011). There was no significant difference among the *assign*, *give*, and *open* situations. The ANOVA results for the subsequent scores showed that a significant difference existed among the four situations, $F_{3,\ 92} = 3.444$, $P = 0.020$. The Scheffé test indicated that the subsequent scores for the *assign* situation were significantly higher than the *rotate* situation ($P = 0.023$). There was no significant difference among the *rotate*, *give*, and *open* situations.

Attitude

Table 2 summarizes the means and standard deviations for student attitudes toward concept mapping and collaborative concept mapping under the four situations. The ANOVA test for attitude toward concept mapping found no significant difference among the four situations. The ANOVA results for attitude toward collaborative concept mapping showed a significant difference among the four situations, $F_{3,91} = 3.024$, $P = 0.034$. However, the Scheffé test was not able to determine which two situations were different because the test is quite conservative (Toothaker 1992, p. 66).

Interaction

Table 3 summarizes the sums, means, and standard deviations for the amount of knowledge-related dialogues among the participants under the four situations. The dialogue amount in the *assign* situation was much greater than that in the *rotate*, *give*, and *open* situations. The ANOVA test for the amount found a very significant difference among the four situations, $F_{3,92} = 7.632$, $P < 0.001$. (Although the assumption of homogeneous variances was violated, the overall *F*-statistic from ANOVA is robust according to Jackson & Brashers (1994, p. 34–35) and Lindman (1974, p. 33).) The Scheffé test indicated that the amount of knowledge-related dialogues in the *assign* situation was significantly greater than that in the *rotate*, *give*, and *open* situations ($P = 0.002$, 0.005, 0.002). There was no significant difference among the *rotate*, *give*, and *open* situations.

While looking into the system database for the utterance sequence by the participants in the *assign*, *rotate*, *give*, and *open* situations, it was found that the collaboration and communication patterns were quite different. In the *assign* situation, most of the group members were more willing to convey their ideas in words about the shared concept map. In the *rotate* situation, the group members tended not to converse with one another but waited for their turn to manipulate directly the shared concept map. In the *give* situation, some group members held onto the mapping control for quite a long time, while some members quickly turned control over to others. When someone had an idea, he/she usually sent a request for the mapping control instead of conveying the idea in words. In the *open* situation, group members often directly manipulated the shared concept map instead of discussing their ideas. When they discovered that other members co-modified the shared map, they would call on the other members to stop, and say '*Who is manipulating?*' or '*Please let me have control?*' Some group members, although not many, would start to mediate the conflicts. They might say: '*Please let XX manipulate first, do you all agree?*'

Table 2. Means and standard deviations (SD) on attitude toward concept mapping (CM) and collaborative concept mapping (CCM).

	CM			CCM		
	n	Mean	SD	*n*	Mean	SD
Assign	24	29.29	4.75	24	46.04	5.93
Rotate	24	27.25	4.80	24	41.25	7.24
Give	23	26.65	4.33	23	41.57	6.19
Open	24	27.00	4.66	24	41.83	5.95

Table 3. Sums, means, and standard deviations (SD) on amount of interaction messages.

	Interaction			
	n	*Sum*	*Mean*	SD
Assign	24	228	9.50	15.24
Rotate	24	13	0.54	0.72
Give	24	31	1.29	2.14
Open	24	15	0.63	0.97

Discussion

Significant differences were found between the *assign*, *rotate*, *give*, and *open* situations in terms of student in-treatment performance and subsequent performance and student attitude toward collaborative concept mapping. The results support that the conflict management mechanism in a collaborative concept mapping system impacts student learning. This finding somewhat corresponds with the study on sharing input devices by Inkpen *et al*. (1997). That study explored the behaviour and learning of students using one shared mouse or two individual mice in collaborative problem-solving games. Two two-mouse cases were investigated: a *give* case, in which the student with control voluntarily relinquished it and a *take* case, in which the student without control pre-emptively acquired it. The choice between these turn-taking protocols was found to have a significant effect on the students.

This study further demonstrated that students in the *assign* situation were superior to students in the *rotate* situation in in-treatment performance and subsequent performance. In addition, students in the *assign* situation would tend to interact more on knowledge construction with their group members than students in the *rotate*, *give*, and *open* situations. The finding that the *assign* design was superior is meaningful for developing a collaborative concept mapping system. This would suggest that the developers of collaborative concept mapping systems should select a limited collaboration scheme to co-ordinate concurrent tasks like restricting the mapping control to a designated member. The suggestion to have one member responsible for mapping manipulation and the other members responsible for observing or commenting also conforms to the idea of implementing role and task divisions to establish interdependence in cooperative learning (O'Malley 1987; Kumar 1996; Brush 1998). In cooperative learning, it is usually recommended that the roles for group members be reassigned to provide each student with the opportunity to perform a different role. However, Brush pointed out that many of the positive social skills and attitudes and academic benefits of cooperative learning tend to emerge and be retained only after students have spent four or more weeks together in the same heterogeneous group. This might provide an explanation for why the 3-min *rotate* situation appeared unsatisfactory.

Compared with the other situations, students in the *open* situation would be thought confronted with more mapping conflicts and these conflicts would obstruct student learning. In this study, although the students in the *open* situation received lower scores in the in-treatment performance and subsequent performance than the *assign* students, the differences were not significant. This study found that a few groups of students in the *open* situation would use their own social protocols to resolve the conflicts. The co-mapping chaos in those groups therefore seemed not that serious. Greenberg and Marwood (1994) also found this phenomenon in general-purpose collaborative systems. They claimed that the conflict management by system was less important or even unnecessary for computer-supported collaborative work. However, this does not suggest using an *open* design. First, the social protocols students evolve might not be appropriate and back up every student's learning. As in this study, most of the social protocols taken by the *open* students were: some group member(s) mediated and asked for agreement to have themselves or capable partners manipulating the shared concept map and leave other members waiting or watching. These students did not produce satisfactory scores in subsequent individual performance. Second, because elementary students normally lack proper interpersonal skills, they must devote a large amount of time negotiating social protocols. This leaves them little time to concentrate directly on knowledge-related discussions. As found in this study, the students under the *open* situation did exchange very few knowledge-related messages.

Conclusion

The findings of this study provide several directions for developing a collaborative concept mapping system for elementary school students. Various conflict management designs involving co-mapping produce different effects. This suggests that the conflict management mechanism choice for a collaborative concept mapping system must be well considered. Secondly, the *assign* design appeared to be ideal and the *rotate* design appeared to be inferior. This would suggest that a collaborative concept mapping system should adopt the *assign* design, even though it is a limited kind of collaboration. The *rotate* design should be avoided. These results may be inferred in the development of systems to support other collaborative tasks, not just concept mapping. If a collaborative system is developed to benefit student learning, selecting an overly complex or flexible conflict management technique may not be necessary. However, further research is required to determine an optimal design for developing other effective collaborative learning systems. Different work styles or phases of work may require different conflict management mechanisms.

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