The evaluation and influence of interaction in network supported collaborative concept mapping

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Abstract

This study investigated group interaction processes in network supported collaborative concept mapping and the influence these group interaction processes had upon group concept mapping performance. A total of 36 in-service teachers and pre-service student teachers engaged in this study. It was found that group concept mapping performance was significantly correlated to the quantity of group interaction, particularly complex co-operation interaction. Suggestions for a further improvement in the system design to support collaborative concept mapping are also provided in this paper. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Computer-mediated communication; Co-operative/collaborative learning; Interactive learning environments; Distributed learning environments; Architectures for educational technology system

1. Background

Concept mapping is a technique for representing knowledge in network graphs. Knowledge graphs consist of nodes and links. Nodes represent concepts and links represent the relationships between concepts (Novak & Gowin, 1984). Through the construction of a concept map (the integration of new or related concepts, establishment of new links or re-arrangement of existing links) learning can be assisted (Novak, 1990). In a meta-analysis of 19 quantitative studies, Horton et al. (1993) reported that concept mapping generally had a positive effect on

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both knowledge attainment and attitude. Traditionally, concept mapping was carried out using paper and pencil. With that approach, two problems usually are encountered. First, students often need to spend significant amounts of time and effort revising and maintaining concept maps, with the result that many students may not concentrate on the body of knowledge. Second, teachers must spend considerable time and effort evaluating each student's concept map. These problems cause the overall concept mapping effect to suffer (Huang, 1995). The personal computer is now being used to support concept mapping and several supporting systems have been developed (Chen, 1997; Fisher, 1990; Fisher et al., 1990; Kozma, 1987; Kozma & Van Roekel, 1986). It is generally agreed that assisted by computers, students can more easily construct, modify or maintain their concept maps and teachers can more efficiently evaluate students' concept maps (Reader & Hammond, 1994).

Concept mapping is usually integrated into co-operative learning activities. Participants are arranged into 3–5 person groups and collaboratively construct their group concept maps. Although few studies have investigated the effects of collaborative concept mapping, most of the studies have found that collaborative concept mapping can lead to effective discussions concerning concepts, and thus enhance meaningful learning (Okebukola & Jegede, 1989; Roth, 1994; Roth & Roychoudhury, 1992, 1993a, 1993b, 1993c, 1994; Roychoudhury & Roth, 1992). With the advancement of network technology, computers can also be used to support collaborative concept mapping just as computers support individual concept mapping. Interconnected computers, digital networks, and the World Wide Web (WWW) make collaborative concept mapping feasible even though attendants are distributed (Chung, O'Neil, Herl & Dennis, 1997).

Although the implementation of network technology to support collaborative concept mapping has been experimental thus far, it is foreseeable that the application will gradually become practical and even widespread. This is evident by the fact that some organizations have made investments into research and development on network supported concept-mapping systems. It is therefore necessary to investigate learning by network supported concept mapping, which may be very innovative and different from learning in traditional collaborative or computer aided individual concept mapping. In order to examine this subjects' problems in depth, this study investigated the interaction patterns among participants, that is, how the participants use communication processes to accomplish the concept-mapping tasks. This study not only provides a better understanding of the essentials of network supported collaborative concept mapping, but also provides directions for the design and improvement of network supported collaborative concept mapping systems.

2. Methodology

2.1. Subjects

This study involved 36 in-service teachers and pre-service student teachers at the elementary level in Taiwan. Their backgrounds were varied, but all took formal training courses in computer operations and applications. The subjects were competent in computer literacy, including the fundamental concepts and skills in using a computer and the Internet. Before

participating in this study, all subjects had some experience in paper-and-pencil based concept mapping, both individually and collaboratively.

2.2. System to support collaborative concept mapping

A system supporting collaborative concept mapping processes was developed for this study. The system was implemented on the WWW platform. Group participants could make use of this system to jointly construct their concept maps by connecting to the Internet and using a web browser (such as Internet Explorer). This system includes four main modules. Figure 1 presents its architecture. Figure 2 shows the user interface to the system.

2.2.1. Communication module
This module provided each group a text-based chat-room, which was a synchronous communication facility exclusive for each group and could not be interfered with by other groups. Participants could type to communicate with their group members wherever they were physically located. They could discuss and reason about the concepts and their interrelations and thus make decisions for the group mapping concepts.

2.2.2. Mapping module
This module provided participant groups, the functions for selecting, moving and deleting concepts and links to construct, modify or reconstruct a concept map. According to Chung et al. (1997), mapping control was given to one individual among each group of participants. The mapping controller could add concepts to a concept map via menu selections and create links by connecting two concepts and then selecting the desired link from a pop-up menu. Every member's computer could be updated as changes occurred. It was decided in this study that a
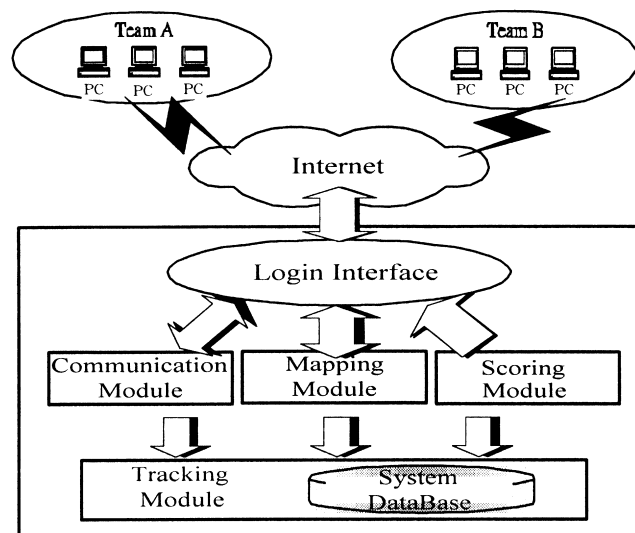

Fig. 1. Architecture of the WWW based collaborative concept mapping system.
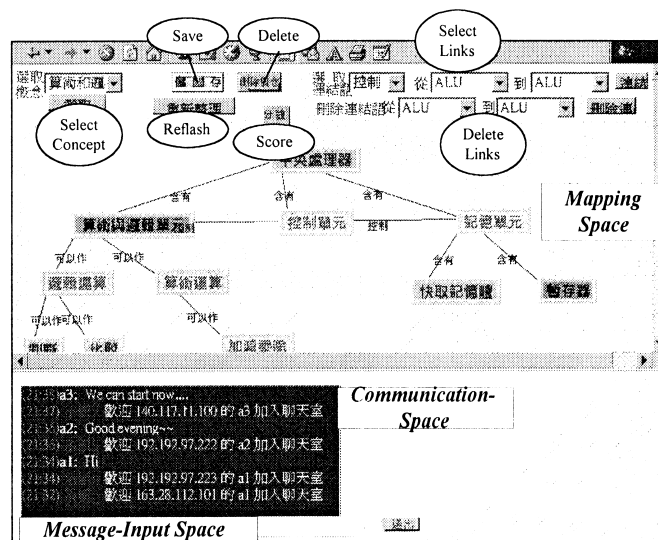
Fig. 2. User interface for the WWW based collaborative concept mapping system.

concept map on a 'central processing unit' was to be jointly constructed. Eleven concepts were predefined, including 'central processing unit', 'arithmetical logic unit', 'control unit', 'memory unit' and so on. Three relationships were provided, including 'contain', 'can do' and 'control'.

2.2.3. Scoring module

This module provides functions to score group concept maps in real time and provides feedback on-line. The scoring mechanics involved comparing the similarities between group-produced maps and an expert's map in terms of the content and structure of the map. Herl, Baker and Niemi (1996) reported that such a scoring approach could yield reliable scores with a strong positive correlation to other content knowledge measures (e.g. essay writing and short answer questions). In this study, the expert's map was quoted from the research of Lin (1998). It was formulated through the fuzzy-set theoretical integration method on three attributed expert concept maps concerning 'central processing unit'. While the concepts or links in the group maps were compared to the expert map, a weighted point was awarded for each match. After the comparison, the score was computed. Group members could request the scores on their concept maps. Information was also provided about possible mistakes. This would further the discussion among group members, since groups would favor better scores and accomplishment.

2.2.4. Tracking module

This module can trace the entire process of each group in concept mapping, including dialog (communication messages) among group members, shared map products from each group and the final evaluation results for the maps. All these data could be stored in a database.

2.3. Procedure

2.3.1. Grouping

This study organized subjects into groups of three members according to Chiu, Chen, Wei and Hu (1999) and Chung et al. (1997). Twelve groups were formed. Each group had a randomly selected leader, who had the authority to produce, manipulate or change the groups' concept map. Non-leaders could only advise by sending messages.

2.3.2. Previous training

Before starting the formal group concept mapping activity, the subjects received a 30-min training on the usage of the WWW-based collaborative concept mapping system, including the operations for mapping concepts and synchronously communicating with one another.

2.3.3. Formal experiment

The subjects were provided 80 min to collaboratively map their group concepts relating to 'central processing unit' using the WWW-based collaborative concept mapping system.

2.4. Analysis of group interaction processes

The interaction processes of each group were reflected in the communication contents. All of the messages within each group were collected and analyzed. A system for the analysis of observable participant interaction behaviors (Fig. 3) was developed based on the Hertz-Lazarowitz (1990, 1992) and Webb (1989, 1992, 1995) studies. The interaction behaviors can be classified into on-task or off-task categories. Co-operation and helping represent on-task
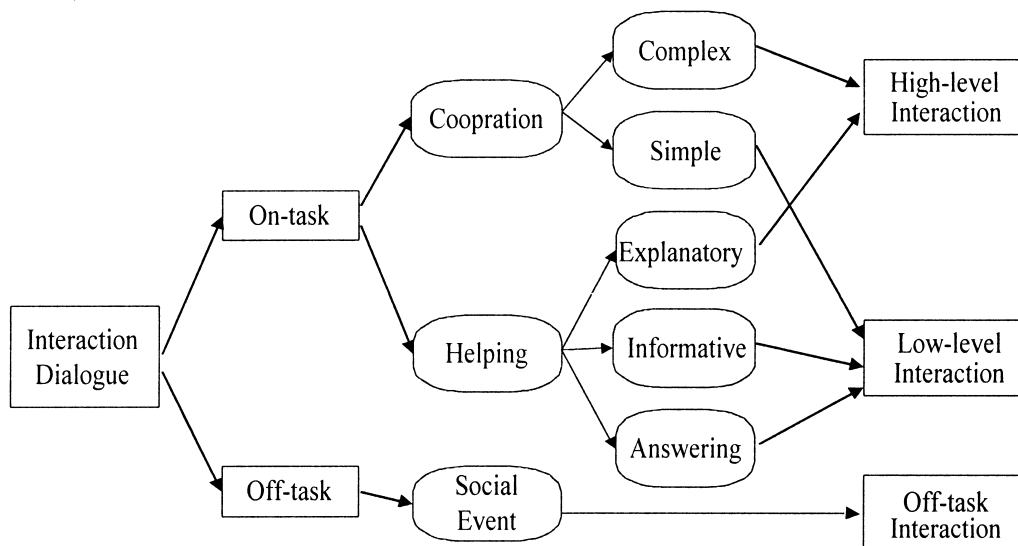

Fig. 3. Analysis scheme for group interaction processes.

Table 1
Definitions and examples of group interaction processes

Behavior category		Description and examples	Category basis
Main observational behavior	subcategory		
Co-operation	simple	co-operation in means or product, without co-operation in the process	interaction/on-task
	complex	co-operation in the process of activity, usually co-operating in a long-term process to create a co-operative product	
Helping	answering	only the answer to a problem or a yes/no response to a question	
	informative	provide information without further explanation or elaboration	
	explanative	detail description of how to solve a problem	
Social event		pupil is engaged in verbal exchange unrelated to the learning activity	interaction/off-task

behaviors and social events represent off-task behaviors. Co-operative behaviors can further be divided into complex and simple categories and helping behaviors into explanatory, informative and answering categories. The complex co-operation and explanatory helping are high-level interactions, while the simple co-operation, informative helping and answering helping are low-level interactions. The details of the categorization are provided in Table 1. Group interaction messages were classified in context. The number of messages for each category were calculated and compared. To further understand how the group interaction processes resulted in group concept maps, the Spearman correlation was utilized on the categorized message count and concept mapping scores.

3. Results and discussion

3.1. Patterns of interaction processes

There were an overall total of 745 messages exchanged among the participants in this study (the 39 error messages were excepted from the count). Of that total, 561 messages (75.30%) were directly related to the concept-mapping task (on-task) and 184 messages (24.70%) were not related to that task (off-task). Among the on-task interactions, 520 messages (69.80%) were used for co-operation, including 464 messages (62.28%) for complex co-operation and 56 messages (7.52%) for simple co-operation. 41 messages (5.50%) were used to help, 16 messages (2.15%) for explanations, 6 messages (0.81%) for information and 19 messages (2.55%) for direct answers. It was found that the messages used for high-level interaction had 480 messages (64.43%) and low-level interactions had 81 words (10.87%). The interaction patterns demonstrated that the participants in network supported collaborative concept mapping were

engaged very much in learning related processes, but were very rarely using the network for socio-emotional or other learning unrelated processes.

3.2. Influence of interaction on group performance

The group concept mapping performance scores ranged from 6.38 to 15.33, with the average being 11.30 and the standard deviation 3.29. The Spearman correlation examination revealed that the group mapping performance was significantly highly correlated to the message amount for group interaction ($r = 0.851$, $p = 0.002$), the on-task interaction ($r = 0.799$, $p = 0.006$), the co-operation ($r = 0.754$, $p = 0.012$), the high-level interaction ($r = 0.872$, $p = 0.001$), and the complex co-operation ($r = 0.872$, $p = 0.001$). It could be concluded that in collaborative concept mapping using a WWW system, the more messages group members exchange or the more they interact, the greater the group formulates its' shared knowledge, and the more superior the group performs on map construction. Among all group interactions, the complex co-operation, which belongs to high-level interaction process, was particularly beneficial. However, the explanatory help was not found helpful in this study. This finding corresponds to many studies in traditional classroom examined by Webb (1989). Webb indicated that the explanation is sometimes helpful, but has to satisfy some necessary conditions of effectiveness.

4. Conclusion

This study discovered that the group performance is related to the amount and the level of group interaction in network-supported collaborative concept mapping. The greater the interaction, particularly the complex co-operation, the better a group performed. Therefore, while selecting a system or an application to support collaborative concept mapping activities, the tools for communication or interactions should be applicable and easy to use. The system must avoid interfering with the desired learning objectives. In addition to the system considerations, interaction processes, particularly related to complex co-operation interaction, should be encouraged and the training for complex co-operation skills should be provided in advance.

Besides the above, a subsidiary finding was observed during the experiment and the analysis processes. It was found that many of the participants were disturbed by their slow typing and thus unable to fully interact within the allotted time. In addition, this study detected that certain messages exchanged among the groups repeatedly occurred. This would prompt that system may provide some assistance for the participants to effortlessly input the common used messages. This study therefore recommends that in terms of designing the communication facility to supported collaborative concept mapping, a system may include an effort-saving and somehow automatic input mechanic for frequent expressions. For example, let users be able to 'type' the frequent messages by a simply click instead of keying every words. This will very likely conquer the slow typing problem, further facilitate communication, improve interaction quality and quantity, and ultimately enhance the overall group mapping performance.

References

Chen, S. F. (1997). *Gainian Goutushi Xuexi Xitong [Computer system for concept mapping]*. Unpublished master's thesis, National Taiwan Normal University, Taipei, Taiwan.

Chiu, C. H., Chen, H. P., Wei, L. C., & Hu, H. W. (1999). Approaching effective network co-operative learning. In *Proceedings of International Conference on Mathematics/Science Education and Technology, San Antonio, TX, USA*.

Chung, W. K., O'Neil, F., Herl, E. & Dennis, A. (1997). *Use of networked collaborative concept mapping to measure team processes and team outcomes*. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Fisher, K. M. (1990). Semantic-networking: the new kid on the block. *Journal of Research in Science Teaching*, *27*, 1001–1018.

Fisher, K. M., Faletti, J., Patternson, H., Thornton, R., Lipson, J., & Spring, C. (1990). Computer-based concept mapping. *Journal of College Science Teaching*, *19*, 347–352.

Herl, H., Baker, E., & Niemi, D. (1996). Construct validation of approach to modeling cognitive structure of US history knowledge. *Journal of Education Research*, *89*, 213–230.

Hertz-Lazarowitz, R. (1990). An integrative model of the classroom: the enhancement of co-operation in learning. In *American Educational Research Association Conference, Boston, MA*.

Hertz-Lazarowitz, R. (1992). *Six mirrors of the classroom: a pathway to co-operative learning*. EI Paso, TX.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993). An investigation of the effectiveness of concept mapping as an instructional tool. *Science Education*, *77*, 95–111.

Huang, T. Z. (1995). *Gainiantu Zai Guozhong Shengwu Jiaoxueshang De Chengxiao Yanjiu (II) [The effects of concept mapping on secondary biology teaching]*. Taipei, Taiwan: National Science Council (NSC 84-25511-S-017-003).

Kozma, R. B. (1987). The implications of cognitive psychology for computer-based learning tools. *Educational Technology*, *27*, 20–25.

Kozma, R. B., & Van Roekel, J. (1986). *Learning tool*. Ann Arbor, MI: Arborworks.

Lin, S. C. (1998). *Shuxinghua gainian goutu de mohu zhenghe he pingli [Fuzzy integration and measurement of attributed concept maps]*. Unpublished master's thesis, National Taiwan Normal University, Taipei, Taiwan.

Novak, J. D. (1990). Concept maps and Vee diagrams: two metacognitive tools to facilitate meaningful learning. *Instructional Science*, *19*, 29–52.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge, London: Cambridge University Press.

Okebukola, P. A., & Jegede, O. J. (1989). Cognitive preference and learning model as determinates of meaningful learning through concept mapping. *Science Education*, *71*, 232–241.

Reader, W., & Hammond, N. (1994). Computer-based tools to support learning from hypertext: concept mapping tools and beyond. *Computers and Education*, *12*, 99–106.

Roth, W. M. (1994). Student views of collaborative concept mapping: an emancipatory research project. *Science Education*, *78*, 1–34.

Roth, W. M., & Roychoudhury, A. (1992). The social construction of scientific concepts or the concept map as conscription device and tool for social thinking in high school science. *Science Education*, *76*, 531–557.

Roth, W. M., & Roychoudhury, A. (1993a). The concept map as a tool for the collaborative construction of knowledge: a microanalysis of high school physics students. *Journal of Research in Science Teaching*, *30*, 503–534.

Roth, W. M., & Roychoudhury, A. (1993b). About knowing and learning physics: the perspectives of four students. *International Journal of Science Education*, *15*, 27–44.

Roth, W. M., & Roychoudhury, A. (1993c). Using Vee and concept maps in collaborative settings: elementary education majors construct meaning in physical science courses. *School Science and Mathematics*, *93*, 237–244.

Roth, W. M., & Roychoudhury, A. (1994). Science discourse through collaborative concept mapping: new perspectives for the teacher. *International Journal of Science Education*, *16*, 437–455.

Roychoudhury, A., & Roth, W. M. (1992). Student involvement in learning: collaboration in science for pre-service elementary teachers. *Journal of Science Teacher Education*, *3*, 47–52.

Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research*, *13*, 21–39.

Webb, N. M. (1992). Testing a theoretical model of student interaction and learning in small groups. In R. Hertz-Lazarowitz, & N. Miller, *Interaction co-operative groups*. Cambridge: Cambridge University Press.

Webb, N. M. (1995). Testing a theoretical model of student interaction and learning in small groups. In R. Hertz-Lazarowitz, & N. Miller, *Interaction co-operative groups*. Cambridge: Cambridge University Press.