Review of Computer-Mediated Collaborative Concept Mapping: Implication for Future Research

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Abstract. In this paper we critically review and analyze previous research on collaborative concept mapping in both face-to-face and networked environments. Although research has shown the positive effects of collaborative concept mapping on learning in face-to-face learning environments, there is a dearth of research which specifically focuses on the potential value of adopting collaborative concept mapping in online learning environments. Newly developed concept mapping software which operates via the Internet makes it possible for distance learners to implement concept mapping as a learning tool for co-constructing knowledge. Using our analysis of current research we provide some directions for future research in the use of concept mapping for online learning.

Keywords: concept mapping, collaborative learning, computer-mediated learning, literature review, assessment

INTRODUCTION

A concept map is a visual representation of knowledge organization that consists of nodes for concepts and links for their relationships (Novak & Gowin, 1984). Educational psychologists believe concept mapping helps people construct conceptual knowledge through externalizing and organizing their implicit knowledge (Jonassen, 2000). Students also report that the activity of developing concept maps helped them learn better because the resulting maps provide external graphical representations of their internal knowledge (De Simone, Schmid, & McEwan, 2001). In addition, collaborative concept mapping has been recognized as an effective strategy for instruction and learning because it requires students to negotiate the meaning of concepts and propositions until all group members agree (van Boxtel, van der Linden, & Kanselaar, 2000). In other words a map serves as a conscription device (Roth & Roychoudhury, 1992) for collectively externalizing mental ideas, which provides a context for sustaining discourse.

According to Vygotsky (1978), an individual's cognitive development is highly affected by one's social relationship with others. He argues that a student reaches his or her *zone of proximal development* (ZPD) – the distance between an individual's actual development level when learning alone and the individual's potential development level with help of adults or advanced peers – through social negotiation and collaboration. During the collaborative concept mapping process, all group members have a chance to listen to each others opinions and arguments about concepts and propositions. Thus we argue that collaborative concept mapping should help students reach a higher level of understanding which may not be obtainable if they draw a map alone.

Despite research identifying the positive effects on cognitive learning outcomes from using concept mapping activities (Komis, Avouris, & Fidas, 2002; Liu, 2002; Stoyanova & Kommers, 2002), concept mapping has been considered time-consuming in terms of drawing, modifying, and assessing a map because people traditionally created concept maps with paper and pencil, and were forced to count the nodes and propositions manually (Chiu, Wu, & Huang, 2000b). Recently, several computer applications (e.g. Inspiration, CMap, Semantica) were developed to support computer-mediated concept mapping which makes the modification of concepts and links easier. In addition, several networked concept mapping applications have the capacity to facilitate geographically separated students share or construct maps together. For instance, CMap is a concept mapping tool which enables students in different places to share their own concept maps. Networked Concept Mapper used in Chung, O'Neil, Herl, and Dennisi's study (1997) supported students to construct maps together by synchronizing all networked computers if any changes are made and by enabling students send a message to each other.

Much of current distance education has been criticized as a replicate of conventional lecture-based classroom education, in which students learn individually with little interaction among peers (Gunawardena & McIsaac, 2004). We believe that networked collaborative concept mapping provides distance learners with opportunities to experience multiple perspectives of others and support for social negotiation processes of knowledge co-construction. However, little research on the use or value of computer-mediated collaborative concept mapping (CCM), especially in online learning environments, has been reported. The purpose of this paper is to review current research on CCM and provide suggestions for future research on computer-mediated CCM. Fourteen empirical studies were selected through searching several academic research literature databases (e.g. Eric, PsycInfo, ESBCO, and ArticleFirst) by using key words including collaborative concept map or mapping.

Table 1 Empirical Studies Reviewed

Category	Face-to-Face CCM	Networked CCM
Empirical Studies	van Boxtel, van der Linden, & Kanselaar (2000)[a]	Chang, Sung, & Lee (2003)
	Coleman (1998)[a]	Chiu (2004)
	Czerniak & Haney (1998)	Chiu, Huang, & Chang (2000a)
	Gilbert & Greene (2002)	Chiu, Wu, & Huang (2000b)
	Ledger (2003)[a]	Chung, O'Neil, Herl, & Dennis (1997)
	Liu (2002)	Komis, Avouris, & Fidas (2002)[b]
	Stoyanova & Kommers (2002)	De Simone, Schmid, & McEwen, (2001)

[a] Technology was not used to mediate CCM. [b] This study consisted of face-to-face learners and distance learners.

ANANLYSIS OF PREVIOUS EMPIRICAL RESEARCH ON COLLABORATIVE CONCEPT MAPPING

According to Jonassen (2000), a concept map can function as a learning tool in four ways: a study guide, a knowledge integration tool, a planning tool, and a tool for assessing what learners know. We found that most studies of CCM in educational settings focused on using a concept map as a social thinking tool (Roth & Roychoudhury, 1992) integrating the functions of a knowledge integration tool and an assessment tool to assess either a collaborative concept map as an end product or collaborative concept mapping as a process or both. Roth and Roychoudhury (1992) argue that considering a concept map as a product is only useful for assessing the product of knowledge co-construction while considering CCM as a learning activity is an ideal tool for assessing the process of meaning negotiation. Further, they suggest that the process of concept mapping as a group activity may be more important than the concept map itself. A map is only a final product but the real learning happens during the process of negotiating, elaborating, and justifying propositions. Therefore, when researchers investigate the effects of CCM, it is necessary to examine not only maps as products but also the meaning negotiation process.

We also noticed some similarities and differences among the research contexts. The group sizes in almost all studies were either dyads or triads. Small groups tend to form a comfortable environment for students to express their ideas for knowledge co-construction and to provide one another with social support (Stacey, 1999). In addition, it seems that dyads or triads are a manageable group size for most CCM activities. We found there are three forms of map creation discussed in the research literature: face-to-face computer-mediated CCM, synchronous networked CCM, and asynchronous networked CCM. While most face-to-face CCM research was conducted in real-life classrooms, almost all studies of networked CCM were conducted in laboratory settings. Specifically, participants were brought into the lab, assigned into small groups, and required to construct a concept map collaboratively only by communicating through networked computers within limited time. Thus, most of the laboratory research findings reported in the literature on how concept maps are constructed collaboratively is not easily generalized into real world learning situations.

Since there is little empirical research on computer-mediated CCM and the nature of task is similar to face-to-face CCM, in our review we included several face-to-face CCM studies in our analysis as long as they were empirically-based and participants were required to create a concept map collaboratively. As a result, we have identified four issues: assessment on a concept map as a product versus CCM as a process, various effects of CCM, scaffolding strategies used in concept mapping, and implementation issues of CCM tasks.

Assessing a Concept Map as a Product and Collaborative Mapping as a Process

In order to assess the effect of computer-mediated CCM on students' learning outcomes, some research simply examined a collaborative concept map as an end product. However some studies also examined the collaborative mapping process in addition to the end products (the maps). Also, we noticed that some researchers were interested only in the group learning outcome; in addition, some researchers were interested in the knowledge gain on an individual level as well.

A scoring scheme was the most commonly used assessment method when a group concept map was used to reflect the group learning outcome. Chiu, Wu, & Huang (2000b) machine-scored students' group maps using a revised scoring scheme originally developed by Novak and Gowin (1984) to examine the components and structure of the maps. In other studies, an expert map was added as a criterion and was compared to group maps using a scoring technique developed by Herl et al. (1996) by examining the similarities and differences between maps in terms of the number of concepts and propositions used and the complexity of the organizational structures (Chung et al, 1997). Rye and Rubba (2002) used a statistical correlation approach to represent the similarity between an expert map and group maps.

In order to fully understand the knowledge co-construction process in a group, some researchers also examined the CCM process. In van Boxtel et al.'s study (2000), students' interaction was coded into utterance and learning episode levels to investigate the discussion about propositions and the conversation on question, conflict, and reasoning among peers. Chung et al. (1997) approached analysis of the CCM process in a different way by examining which message types (i.e. adaptability, coordination, decision making, interpersonal, leadership, and communication) during the collaboration were most effective in creating a better concept map. Chiu et al.'s study (2000b) focused on what process each group took to complete a concept mapping task in a networked CCM and how those different interaction patterns influenced the group concept maps. They found that the group focusing on generating one or two propositions and progressively expanding the map created a better concept map than other groups using the other interaction patterns.

A desired group learning outcome does not guarantee that each individual in a group learn equally well. To assess individual internalization, Stoyanova and Kommers (2002) examined whether the concepts appearing in the group map also transferred to individual maps created one week later. An alternative way was to require them to do an individual task reflecting their level of integration of concepts in CCM (Gilbert & Greene, 2002) or take objective tests about the topic used in CCM (van Boxtel et al., 2000). In this case, the researchers wanted to examine an individual's level of understanding transferred after collaboration.

The Effects of Collaborative Concept Mapping

The effects of CCM have been researched in both the affective and cognitive aspects. CCM was found to have no significant effect on science self-efficacy of female eight grade students (Ledger, 2003) and on pre-service teachers' self-efficacy on learning and teaching physical science (Czerniak & Haney, 1998). However, pre-service teachers who constructed a concept map with Inspiration in a group reported a lower anxiety level on learning and teaching physical science than those who had not constructed a concept map at all.

From a cognitive aspect, pre-service teachers in a CCM class outperformed those in an expository class in the final exam which tested students' level of understanding of physical science concepts (Czerniak & Haney, 1998). Another example can be found in Stoyanova and Kommers' study (2002) in which they report undergraduate students outperformed counterpart students in solving ill-structured problems when they constructed CCM together. Gilbert and Green (2002) also reported that students in a group, who actively engaged in constructing a concept map, integrated concepts from the map into their final individual projects much better than those in groups in which a group concept map was done either by "sewing" divided individuals' works or by only one member. Since almost all the studies above were done in face-to-face environments, we are not sure similar research would produce the same results in online learning environments. More empirical research on the effects of CCM in online settings would provide valuable information for online educators and online instructional designers.

Scaffolding Strategies Used in Concept Mapping

Previous research adopted and implemented a variety of ways to shape or scaffold students' concept mapping activities. Several research experiments provide students with predefined concepts, relations, and message types in order to help them focus on the core concepts of a topic and promote the collaboration process (Chiu, et al., 2000a; Chiu, et al., 2000b; Chung et al., 1997). Another type of scaffolding strategy was using explanation prompt questions (Coleman, 1998). During the mapping and problem-solving process, group members took turns as a prompter and asked other group members to elaborate their justifications of propositions and solutions they suggested. A sample prompt question included, "explain why you believe that your answer is correct or wrong." The explanation prompt questions were used to force the students to elaborate their thinking in order to promote discussion among students.

The findings from aforementioned research indicates that limiting message types hindered students from deeply engaging in discussion about the content because they had to spend considerable amount of time in selecting a message (Chung et al, 1997). In contrast, the explanation prompt questions embedded in the concept mapping and problem solving process had a positive effect on students' usage of intuitive and scientific links for both the individual and collaborative performance (Coleman, 1998).

Implementation of Collaborative Concept Mapping Task

Several issues related to the implementation of CCM tasks have been identified. Students should be prepared for the topic which they will construct on a concept map. Chung and his colleague (1997) reported that students could not deeply engage in the task because they were not familiar with the topic itself. Students should be provided with a sufficient training on how to create a concept map and use a concept mapping tool in order to make sure they have necessary skills to perform the given task. In addition, possible technological problems should be identified and solved prior to engaging students in the task. For instance, the cross-platform compatibility issue of mapping software needs to be taken into account. In the De Simone, Schmid, and McEwan's study (2001), students encountered technical difficulties with PIViT, which is a PC-only concept mapping tool, and thus switched to use Inspiration in the middle of the course.

Students should be guided on how to collaborate effectively and efficiently. In van Boxtel at el.'s study (2000), groups in which members prepared concepts individually before engaging in the CCM created better concept maps and asked more questions to each other than groups in which member did not prepare anything before collaboration. Another related issue is the use of management mechanisms, or authorship, in co-constructing a map together. It can be problematic in networked CCM when members try to modify a map simultaneously. Chiu (2004) suggested four protocols of managing networked CCM in a synchronous situation: assign, rotate, give, and open protocols. Although he found that the assign protocol, having one member responsible for mapping manipulation and the other members responsible for observing or commenting, was superior to the other management protocols in managing the process, we need more research in this topic. We also found from the review that 'collaboration' can be interpreted differently by students. In Gilbert and Greene's study (2002), when students were asked to construct a concept map collaboratively by adding at least 5 concepts per person, each group took various ways of collaboration either by dividing tasks and sewing them together, letting one student to complete a map alone, or actively constructing a map together through social negotiation of meaning.

CCM takes time because it requires a group to do decision-making together. Several studies, especially the laboratory ones (Chiu, et al., 2000a; Chiu, et al., 2000b; Chung et al., 1997), required a group of students to build a concept map in a relatively short period of time, less than one hour. To be more realistic, a group of students should be allowed to build a concept map in a reasonable time frame because CCM requires students to make decisions together through social negotiation.

CONCLUSION

Based upon the analysis of previous research on computer-mediated CCM, we have identified four suggestions for further research. The best way for researchers to investigate the true effect of CCM, is to assess the process of CCM along with examining the end product (the concept maps) because it more likely will illuminate how the collaboration process influences knowledge co-construction. Driscoll (2001) argued that assessment of CCM as a process is a more productive line of research. Also, Stoyanova and Kommers (2002) supported their idea by arguing that learning effectiveness depended not only on the result but also on the learning process taking place via social interaction.

Individual internalization should be also assessed as well as group outcomes. Although group maps show group members' consensus on the meanings of concepts and propositions, we cannot assume that all the members in a group would end up with the similar level of understanding and knowledge (Roth & Roychoudhury, 1992). Individual cognition is the interplay between situations where group members construct meanings together through social negotiation and where individuals actively construct his/her own meaning.

We also agree with Johnson and Johnson (1994) that individual accountability should be ensured in collaborative tasks to prevent free riders. Little research, however, actually examined individual accountability. Gilbert and Green (2002) required groups of students to submit group reflection papers reflecting group working process. Also, peer review is a widely used technique to ensure or encourage individual accountability.

Newly emerging technologies enable researchers to study CCM even with distance learners, and to track students' dialog and their concept map development process. For example, Networked Concept Mapper used in Chung et al's study (1997) and Representation 2.0 used in Komis et al.' study (2002) support a function that students can build a concept map collaboratively even in a distance by sharing screens and text-based chat-rooms which can be saved easily for further content analysis.

Finally, the implementation process should be cautiously designed and monitored. Students can interpret 'collaboration' differently. For instance, several groups in Chang, Sung and Lee's study (2003) submitted a group map by selecting the most complete individual map and revising it. In Czerniak and Haney's study (1998), individuals' maps were combined and submitted as a group map or one member did almost all the work. We hope that our review will provide some directions for more productive research in the use of concept mapping for online learning.

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