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COLLABORATIVE CONCEPT MAPPING IN EDUCATION: MAJOR RESEARCH TRENDS

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Abstract. Since the late eighties, more and more researchers have been exploring the potential of collaborative concept mapping to support learning. In those studies, students construct concept maps in pairs or in small groups. This paper presents a review of research trends on collaborative concept mapping in education. We present an overview of the theoretical framework, methodology and main results of 39 published studies investigating this topic.

1 Introduction

In the last decade, the socioconstructivist paradigm has become increasingly predominant in education, where collaborative learning is considered as being beneficial to learning. Since the late eighties, some researchers have been exploring the potential of collaborative concept mapping (CCM) to support learning. In those studies, students construct concept maps in small groups. With the development of concept mapping (CM) software and web-based technologies, CCM, either at a distance or in a face-to-face condition, has become even more popular. Thus, research on CCM has thrived in the last years. However, reviews of research on CM in education (e.g. Horton *et al.*, 1993; Nesbit & Adesope, submitted) do not specifically address issues related to the collaborative context of the CM activity in some studies. This paper presents trends from a review of 39 published studies on CCM. Those studies were found using *ERIC*, *FirstSearch*, and *PsychFirst* databases. The proceedings of the *CMC 2004 Proceedings* were also searched. An overview of the CCM studies found is presented in Table 1. Only one study has been conducted before the nineties, 12 in the nineties, and 26 since 2000. This confirms that research on CCM has intensified in the last years.

2 Theoretical framework and research methods of studies on collaborative concept mapping

Fourteen studies did not specify a theoretical framework related to the collaborative nature of their research. Sociocultural learning (e.g. Vygotsky, 1978), symbolic interactionism (e.g. Mead, 1934/1974), sociocognitive conflict theory (Mugny, Perret-Clermont, & Doise, 1981), and situated learning (e.g. Rogoff & Lave, 1984) frameworks are mentioned in 6 to 8 studies in each case. Four studies refer to the collaborative learning literature (e.g. Slavin, 1990; Deutsch, 1949). Distributed cognition (e.g. Salomon, 1993) appeared in some studies after the year 2000. Other theoretical frameworks (teamwork and relational cognition) are mentioned in three studies.

Research methods used by CCM researchers are mostly experimental (21). Non-experimental methods (action research, qualitative research, etc.) were also quite popular (15), especially those investigating social interactions during CCM. Only three studies used quasi-experimental methods, (with non-randomized samples). The majority of studies (22) had less than 50 participants with a range from 15 to 808 and a mean of 76 (see Table 1). Twenty-five studies were done with students in higher education and 14 were done with students in grade school. Of the 39 studies, the Sciences were used most often as CM topic (24). Education came in a close second with 12. Thirty studies created teams of two or three. Twenty-two studies used some grouping criteria (gender, ability, familiarity, etc.). In two cases, the CCMaps were produced by the class as a whole. In most of the studies (28), participants used digital CM tools. Nine used non-digital tools and two used both. Four studies do not specify what tool was used (probably paper-and-pencil). Sixteen studies specified that communication during CCM was done face-to-face. Digital tools were used for communication in 19 studies and 13 of those used chat. Nine studies specified some communication constraints. In seven cases, predefined roles were imposed (e.g. leader, explainer, advisor, etc.), four of them being rotating roles. Predefined messages were used in 6 cases (complete messages or message stems). During the CM task, 16 studies used predefined nodes, four predefined node types, 11 predefined links, four predefined link types, and nine used other constraints. These conditions are not mutually exclusive (see Table 1). It is difficult to determine the duration of the studies because, although they may explicitly state their time frame, we cannot identify how long students spent constructing CCMaps. In seventeen studies, participants created a CCMap in one session lasting from 36 to 120 minutes. The same number of studies based their analysis on multiple CCM sessions, with a wide range from one week to one year. In those cases, we do not have the exact time students actually spent on the CCM task. Five studies did not specify the duration of the CCM task at all.

Table 1 – Studies on Collaborative Concept Mapping[1]

Authors & Year	Participants & Topic	Grps	CM Tool	Compared groups	CM Task	Comm. Tool
(Okebukola & Jegede, 1988)	145 HE Biol.	5	ND	CCM, ICM, OIA	-	F2F
(Okebukola, 1992)	60 HE Biol.	5	ND	CCM, ICM, OIA	F	F2F
(W.-M. Roth & Roychoudhury, 1992; W. Roth & Roychoudhury, 1993)	148 HE Physics	3-4	ND	CCM	PN	F2F
(Esiobu & Soyibo, 1995)	808 S Biol.	5	ND	CCM Coop, CCM Coop-comp, ICM, OCA Coop, OCA Coop-comp, OIA	F	F2F
(Reinhard, Hesse, Hron, & Picard, 1997)	60 HE Biol.	2	D	All CCM: Manipulable graphics, Static graphics	Other	Chat
(Sizmur & Osborne, 1997)	84 P Sciences	-	ND	CCM	PN	F2F
(van Boxtel, van der Linden, & Kanselaar, 1997, 2000)	40 S Sciences	3	ND	CCM (w/ individual preparation) CCM (w/o individual preparation) OCA (w/ individual preparation) OCA (w/o individual preparation)	PN	F2F
(Coleman, 1998)	48 P Biol.	3	ND	All CCM: High intentional learners (w/o prompt), Average intentional learners (w/prompt), Average intentional control (w/o prompt)	PN PL	F2F
(Czerniak & Haney, 1998)	118 HE Sciences	Class	D (PIVIT)	CCM, OIA	F	F2F
(Chung, O'Neil, & Herl, 1999) (Pilot Study)	30 S Envir. Sc.	3	D	CCM	PN PL	Chat
(Chung, O'Neil, & Herl, 1999) (Main Study); (Herl, O'Neil, Chung, & Schachter, 1999)	111 S Envir. Sc.	3	D	CCM	PN PL	Chat
(Osmundson, Chung, Herl, & Klein, 1999)	52 P Biol.	3-4	D	CCM, OCA	PN PL	Chat
(van Boxtel & Veerman, 2001)	20 S Educ.	2 -3	D (Belvedere)	CCM	PN PL	Chat
(Chiu, Huang, & Chang, 2000)	36 HE Comp.HW	3	D	CCM	PN PL	Chat
(Chiu, Wu, & Huang, 2000)	30 P Comp. HW	3	D	CCM	PN PL	Chat
(Fischer & Mandl, 2000)	48 HE Educ.	3	ND D (CoStructure)	All CCM: F2F Domain-Specific Tool, F2F Domain-Unspecific, Online Domain-Specific, Online Domain-Unspecific	PL Other	Video-conf.
(De Simone, Schmid, & McEven, 2001)	26 HE Ed.Tech.	3-5	D (PIVIT, Inspiration)	CCM	F	F2F (forum not used)
(Fischer & Mandl, 2001, , 2002)	64 HE Educ.	3	ND D (CoStructure)	All CCM: F2F Domain-Specific Tool, F2F Domain-Unspecific, Online Domain-Specific, Online Domain-Unspecific	PL Other	F2F Video-conf
(Kealy, 2001)	13 HE Educ.	2- 3	D (Inspiration)	CCM	PN	F2F
(Suthers & Hundhausen, 2001)	60 HE Sciences	2	D (Belvedere)	CCM, OCA (Matrix), OCA (Text)	PNT PLT	F2F

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[1] Legend:
Participants: **H**igher **E**ducation; **S**econdary; **P**rimary.
CM Tools: **D**igital; **N**on-**D**igital.
Compared Groups: **C**ollaborative **C**oncept **M**ap; **I**ndividual **C**oncept **M**ap ; **O**ther **C**ollaborative **A**ctivity; **O**ther **I**ndividual **A**ctivity.
CM Task: **F**reestyle; **P**redefined **N**odes; **P**redefined **L**inks; **P**redefined **N**ode **T**ypes; **P**redefined **L**ink **T**ypes.

Authors & Year	Participants & Topic	Grps	CM Tool	Compared groups	CM Task	Comm. Tool
(Fischer, Bruhn, Gräsel, & Mandl, 2002)	32 HE Ed.Psych.	2	D (CoStructure)	All CM: Domain-Specific Representation Tool, Domain-Unspecific Representation Tool	PL Other	F2F
(Gilbert & Greene, 2001-2002)	15 HE Ed.Tech.	3	D (Inspiration)	CCM	PN Other	F2F
(Komis, Avouris, & Fidas, 2002)	17 HE Computing	2	D (Representation	CCM	-	Chat
(Stoyanova & Kommers, 2002)	36 HE Ed. Tech.	4-5	D (Inspiration)	ICM Distributed mapping (shared ICM), ICM-Moderated mapping mode (Shared ICM adjusted by moderator), CCM-Shared mapping mode (synch), OCA (outline)	F	F2F
(Suthers, Girardeau, & Hundhausen, 2002)	20 HE Sciences	2	D (Belvedere)	All CCM: F2F, Distance	PNT PLT	F2F, Chat (distance group)
(Chang, Sung, & Lee, 2003) (Study 1)	17 HE Hist.	2– 3	D	CCM	F	Chat
(Chang, Sung, & Lee, 2003) (Study 2)	23 HE Educ.	3-4	D	CCM	F	Chat
(Ledger, 2003)	226 S Astron.	2-3	ND	CCM, OIA	-	F2F
(Suthers, Girardeau, & Hundhausen, 2003)	40 HE Sciences	2	D (Belvedere)	All CCM: F2F, Distance	PNT PLT	F2F, Chat
(Basque & Pudelko, 2004)	48 HE Ed. Tech.	2	D (MOT)	All CCM: Email, Chat, F2F	PNT PLT	Chat, Email F2F
(Chiu, 2004)	96 P Sciences	3	D	All CCM: Assign, Rotate, Give, Open	PN PL	Chat
(Depover, Quintin, & De Lièvre, 2004)	18 HE Educ.	2	D	All CCM: Contrasted pairing based on previous ICM, Self-selected	PN	Forum
(Karasavvidis, 2004)	54 P Hist.	2-3	D (Inspiration)	CCM	-	F2F
(Khamesan & Hammond, 2004)	30 HE Web Design	2	D (Cmap)	All CCM: F2F, Online w/chat, Online w/audio and chat	F	F2F Chat Audio
(Liu, 2004)	15 S Chem.	2	D (Inspiration)	CCM	-	F2F
(Silander, Sutinen, & Tarhio, 2004)	20 P Biol.	Class	D (MoCoCoMa)	CCM	F	Chat, SMS
(Khamesan & Hammond, 2005)	60 HE Web Design	2	D (Cmap)	All CCM: Web-based Shared Interaction, Web-based moderated interaction (Assign 1 member as editor), Non web-based distributed interaction (rotate each 10 min.)	F	Chat + audio
(Kinchin, De-Leij, & Hay, 2005)	150-180 HE Biol.	5	ND	CCM	PN	F2F
(Lee & Nelson, 2005)	44 HE Ed.Tech.	2	D (Inspiration)	All CCM: High K/Generative CM, High K/Completed Map, Low K- Generative Map, Low K/ Completed map	PN	F2F

3 Results of the studies on collaborative concept mapping

The issue of the ***effect of CCM on task performance*** (quality of the CCMaps) had been investigated in 19 studies. Some researchers explored this issue from a developmental perspective (Kealy, 2001; Karasavvidis, 2004; Liu, 2004). In 10 cases, the CMaps were analyzed with a qualitative scheme. Two studies show that CCMaps are better scored than individual CMaps (Okebukola & Jegede, 1988; Czernizk & Haney, 1998). Other researchers examined the effect of varied conditions of CCM on task performance. For example, Coleman (1998) found that "average intentional learners" performed better than their counterparts at CCM tasks if they are prompted, and similarly to "high intentional learners" who are not prompted. Fisher *et al.* (2002) found that the use of a content-specific computer-based CM tool results in better CCM performance than a content-unspecific one. Stoyanova et Kommers (2002) found that a "shared" mapping mode (synchronous CCM) results in better performance compared to a distributed mode (shared individual CMaps until a common vision is attained) and a "moderated" mode (shared individual CMaps adjusted by a moderator). Chiu (2004) found that performance is lower when roles are rotated than when they are assigned, given, or left open. In another study, groups of students of mixed individual CM ability did not produce better CCMaps than self-selected groupings (Depover, Quintin & De Lièvre, 2004). Three studies compared task CCM performance in a face-to-face (F2F) context and in a distance one. Basque & Pudelko (2004) found that the performance in a F2F condition is better than in an asynchronous one (email). When a F2F condition is compared to a synchronous one (chat with or without audio), no significant difference was found in group achievement in the Khamesan & Hammond studies (2004; 2005).

The ***effects of CCM on learning***, as measured by post-CCM measures (achievement test, problem-solving test, comprehension test, individual CMaps produced after the collaborative CM activity, etc.), are investigated in 22 studies. Compared to individual CM or to other types of collaborative activities (e.g. producing an outline or a matrix representation) CCM has been found to be more beneficial for learning (Okebukola & Jegede, 1988; Eseiobu & Soyibu, 1995; Czeniak & Haney, 1998; Osmundson *et al*., 1999; Stoyanova & Kommers, 2002; Ledger, 2003). However, we also found some "no-significant-difference" studies (Okebulola, 1992; van Boxtel *et al*., 1997, 2000; Suthers & Hundhausen, 2001). Other researchers explored the differential effect of varied CCM conditions on learning. For example, Reinhardt & al. (1997) found that using a manipulable graphical CCM tool lead to better learning than using a static graphical version of the tool during a problem solving post-test. Suthers, Girardeau & Hundhausen (2003) observed no significant difference between F2F and distance groups in a memory-based post-test, but F2F groups performed better on written essays produced after the CCM activity (Suthers, Girardeau & Hundhausen, 2003). Findings of Fischer & Mandl (2000; 2001; 2002) did not show any impact of different communication modes (F2F *vs* online) and tools (domain-specific *vs* domain-unspecific) on knowledge construction. Similarly, Basque & Pudelko (2004) did not observe a difference in comprehension post-test between groups using F2F or distance mode of communication (chat or email) during a CCM activity. Khamesan & Hammond (2004) obtained similar results with post-test individual CM comparing F2F and synchronous distance conditions (chat with or without audio). In a subsequent study, however, they found that a "non web-based distributed interaction" (one student working on the CMap during ten minutes and then passing it on to his partner, without visualizing each others' processes) lead to higher "knowledge acquisition" than synchronous ones. Knowledge acquisition was measured by calculating the total number of new concepts included in the post-individual CMap compared to the pre-individual CMap. However, there was no statistical significant difference among the conditions in means of participants' individual creativity and retention. Chiu (2004) found that triads with assigned roles using a web-based CM system with built-in predefined messages obtained higher scores on post individual CM compared to triads with rotating roles (every three minutes). Finally, Lee & Nelson (2005) found that groups which generated CCMaps performed better at problem-solving than groups which simply completed CCMaps.

Approximately half of the studies investigated the ***interactions between students during CCM***. Roth & Roychoudhury (1992, 1993) are among the first researchers to study this issue. Using qualitative research methods, they observed sustained science discourse during CCM in junior and senior physics classes, and that this discourse replicates the typical interactions in scientific communities, that is, co-construction interactions, adversarial interactions and formation of alliances. Sizmur & Osborne (1997) also observed "the phenomenon of children's continuing each other's contributions" during CCM, which allowed participants to make more scientifically valid propositions than non elaborated exchanges. van Boxtel *et al.* (2000) observed a larger quantity of elaborated cognitive conflicts and of constructed reasoning episodes between pairs creating a CCMap than those who created posters. However, in the Chang, Sung & Lee (2003) study, adult participants were not so prone to negotiate their ideas, but it should be mentioned that, in that case, one member of the group was elaborating the map, while others were giving comments and suggestions.

Other studies investigated computer-based interactions or web-based interactions (at a distance) during CCM. Some authors found that interactions, in those contexts, are on-task most of the time (Chiu, Huang, & Chang, 2000; Chung, O'Neil, & Herl, 1999; Komis, Avouris, & Fidas, 2002), although that was not the case in the van Boxtel & Veerman study (2001). Other researchers pinpointed some difficulties during CCM at a distance. Chiu, Huang, & Chang (2000) noted that slow typing seemed to have disturbed participants who used chat as a communication tool during CCM. They also observed a great amount of repetitive messages, which lead them to conclude that the communication tool should integrate predefined messages. Many other authors also proposed to introduce some kind of structure in the collaborative activity or tool to facilitate content-related interactions and to enhance the depth of processing in a distance mode of communication during CCM. This is the case for Fischer & Mandl (2001) who observed an inadequate division of labour in the distance groups. Van Boxtel & Veerman (2001) observed that student groups need a high amount of effort to coordinate their communication via a CCM tool integrating a chat. Reinhard & al. (1997) found the same, when comparing interactions in a group of students that had to communicate via a chat to correct computer graphics, either in the condition “manipulable graphics” or in the condition “static graphics”. Students in the former condition tended to have a greater need for coordination effort. Suthers, Girardeau, & Hundhausen (2002, 2003) noted a lack of deictic power of CCM tools used at a distance. This could explain why distal participants rarely referenced items that had been previously represented, except for those that had just been added. These authors suggest that tools should support “fluid crosstalk between all representations by making the relationships between different representations and between acts on those representation clear” (p. 13). Chiu, Wu, & Huang (2000) identified four patterns of computer-mediated CCM processes: (1) Concept introduction; (2) Limited concept introduction; (3) Less link establishment; and (4) Proposition construction orientation. Depover, Quintin, & De Lièvre (2004) found that metacognitive interactions and planning interactions were more frequent in contrasted pairings (based on pre-test individual CMap) than in spontaneous ones. However, the last were more collaborative.

Correlations between interactions during CCM and task performance are investigated in four studies (Chiu, Huang, & Chang, 2000; Chung, O’Neil, & Herl, 1999; Depover, Quintin, & De Lièvre, 2004; Sizmur & Osborne, 1997). In general, results show that more interactions and more elaborated, high-level, and complex interactions lead to better performance. There was, however, an exception of one computer-based CCM study (Chung *et al*., 1999) in which the number of chat messages was correlated negatively to performance. Authors explain that split attention effect (Sweller, 1994) could have induced too heavy a cognitive load on participants and that “the use of messages may reflect more the procedural aspects of constructing a knowledge map instead of any substantive discussion about the content” (p. 490).

Only one study explored ***correlations between interactions during CCM and learning*** *(*van Boxtel, van der Linden & Kanselaar studies, 1997, 2000). Results show that the frequency of “elaborative episodes” during CCM is correlated with learning.

Seven studies explored the ***effect of CCM on attitudes***. The results of the study of Czerniak & Haney (1998), conducted with preservice teachers, indicate that CCM could lower anxiety about learning physical science, lower trait anxiety, and increase science achievement. However, it did not have a significant effect on anxiety toward teaching physical science, self-efficacy, and outcome expectancy. Ledger (2003) arrived at the same conclusion for self-efficacy with eighth grade students. However, this author found that female students in the CCM group had a more positive attitude toward science than those that did not construct CMaps. This result was not observed for male students. Attitude toward CM was not significantly altered in groups that experienced CCM with different roles’ distribution (assign, rotate, give, or open) according to Chiu (2004). Other authors report opinions from students who experienced CCM. Chang, Sung, & Lee (2003) found that 53% of them were not satisfied with the CCMaps they produced. However, other studies indicate that students appreciate the CCM activity (Liu, 2004; Silander, Sutinen, & Tarhio, 2004). Interpersonal awareness was investigated in the Khamesan & Hammond studies (2004, 2005) comparing online CCM with F2F CCM. In their first study, they found that participants using audio/chat communication showed lower levels of interpersonal awareness and lower performance in a reaction measure compared to F2F and to the chat only group. However, in their subsequent study, there was no significant difference in interpersonal awareness between web-based and non web-based (but distributed) interactions groups, although awareness was higher for web-based groups (specially shared interaction).

Finally, we identified a few ***other issues*** (cognitive preference, gender, etc.), that are explored in some CCM studies. For example, Okebukola & Jegede (1988) found that subjects that have a cognitive preference for *Principles* (i.e. an interest in identifying a relationship between variables or a rule that can be applied to a class of objects, phenomena, or an interest in explaining phenomena), for *Questioning* and for *Application* scored significantly higher in the CCM condition than those who worked individually. No significant difference was found in the CM performance of students with *Recall* cognitive preference in the two learning modes. In a subsequent study, Okebukola (1992) found that students that had six months of CCM experience and that were judged as “good concept mappers” had the highest mean score at a problem solving test than good concept mappers that experienced individual CM and subjects that had no CM experience. The girls outperformed the boys in one problem but the boys displayed better problem-solving abilities in the two others. Girls in the CCM group did better than those in the CM group on two problems. The author concluded that “this may be a hint that cooperative-learning experience is more advantageous than individual work for girls for enhancing problem-solving skills through concept-mapping.” (p. 168).

4 Conclusion

This paper (too) concisely described the research that has been done so far in the field of CCM. It is obvious that this is a domain that is becoming increasingly active as we reaffirm the benefits of collaborative learning. Further analysis is needed to better understand how CM fits into this type of learning. We also encourage more sound research in this domain, especially investigating correlations between types of interactions and learning during the CCM activity.

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