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Fostering Interdisciplinary Knowledge Construction in Computer-Assisted Collaborative Concept Mapping

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Abstract. Research on individual and group cognition has argued that the way learning activities are sequenced over different social levels has an effect on learning effectiveness. This study investigates the effect of embedding an individual preparation phase prior to collaborative concept mapping (CCM) on the epistemic and social dimension of the CCM process. Using a quasi-experimental design, a multi-disciplinary group of 24 3rd year bachelor students attending a minor entrepreneurship are put into two different conditions: one with individual preparation phase (WIP) and one without individual preparation phase (WOIP). The students worked on a collaborative assignment about macro trends analysis using computer-assisted CCM. For the epistemic dimension, students in the WIP condition showed more occurrences of utterances seeking clarification and positioning one's perspectives. In the social mode of knowledge construction, students in the WIP condition displayed more conflict-oriented and integrated consensus building statements to negotiate shared knowledge. We discussed these findings against the background of literature on negotiating common grounds and converging at shared knowledge with a focus on the epistemic dimension and social modes of knowledge co-construction in computer-assisted collaborative learning.

Keywords: Collaborative concept mapping, interdisciplinary knowledge integration, common grounds, social modes of knowledge co-construction, epistemic dimension of knowledge co-construction

1 Introduction

Contemporary problems are often transcending the boundaries of a single discipline. This implies a need to integrate knowledge from different disciplines [1]. According to Songer and Linn [2] knowledge integration could be perceived as synthesizing concepts and ideas from different disciplines into a coherent whole. To this end, collaborative knowledge construction (CKC) could play an instrumental role [3]. However, coordination, communication and interaction challenges ensue when individuals from various disciplines construct shared meaning and knowledge [4]. In this regard Novak and Cañas's [5] studies showed the pivotal role of collaborative concept mapping (CCM) in providing a graphical representation of concepts and relationships. Researchers have found that CCM enhances coordination and communication within groups, which in turn, facilitates a more integrated conceptual framework with more types of links between the different concepts [6]. Notwithstanding the plethora of research on CKC and the use of CCM to facilitate this process, there remains paucity of empirical works on interdisciplinary knowledge constructing using CCM. Hence, this research study focuses on the processes of CCM. Specifically, it investigates how the sequencing of learning activities, i.e., embedding an individual preparation phase prior to collaborative work, could have an effect on the interdisciplinary knowledge co-construction process during collaborative concept mapping.

1.1 Challenges of Collaborative Knowledge Construction

According to social constructivists like Palincsar [7] learning is a social process and knowledge is a negotiated product of a collaborative discourse [8]. Hewitt and Scardamalia [9] liken the CKC process to "distributed cognition" where "each person's individual cognitions are continually reorganized in an effort to construct meaning out of the other person's speech acts" (p.79). The interwoven nature of individual and social processes imposes a high degree of (meta) cognitive demands. Beers et al. [1] captured the challenges of CKC in four main stages (see Fig.1): knowledge externalization, internalization, negotiation and integration. A first step in CKC is externalizing unshared knowledge. This requires students to activate their prior knowledge. Many students have difficulties activating the implicit knowledge [10] that is often unstructured and stored in long term memory [11]. Knowledge externalization in multi-disciplinary teams is more difficult because there is little prior knowledge of each other's field. The next step is knowledge internalization, which involves interpreting and understanding shared knowledge. Because of different perspectives, ways of thinking and types of jargon it is often complicated to get an accurate idea of what the others from a different discipline have shared [6, 12]. In interdisciplinary knowledge co-construction, members have to analyze multidisciplinary problems. Hence, bridging different perspectives and finding common grounds to arrive at shared knowledge becomes pivotal in the third stage of negotiation [1, 13]. In the final stage of knowledge integration, members have to deal with fragmented thinking and structuring knowledge. Very often, categorizing and synthesizing the different knowledge contributions pose a tremendous challenge in the knowledge integration phase.

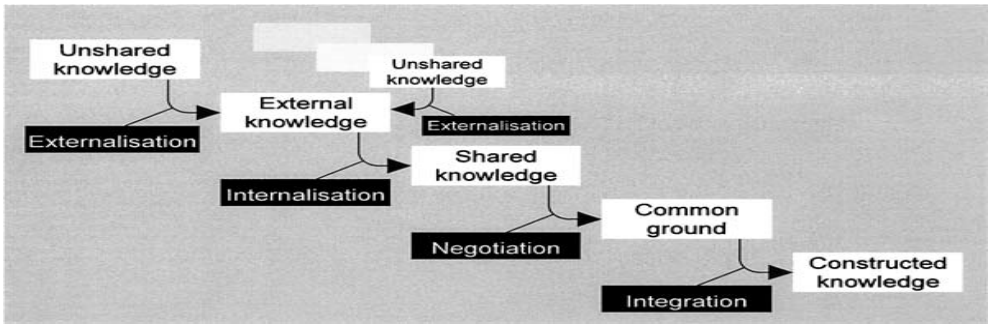

Fig. 1. From unshared knowledge to constructed knowledge (Beers et al., 2006)

1.2 Facilitating Interdisciplinary Knowledge Construction with Concept Maps

Concept mapping is an effective measure to scaffold the complex CKC process. It builds on the principles of social constructivism [14]. Concept mapping facilitates the activation of prior knowledge by enabling learners to structure their knowledge. It scaffolds knowledge externalization and internalization more effectively than text [6, 15]. The explicit representation of mental models facilitates the grounding process where concepts and relationships can be more effectively negotiated [16, 17]. Research showed that concept maps structure the collaborative discourse and fosters more in-depth and productive interaction [18]. This could lead to integration of different knowledge contribution [19, 20]. Albeit concept mapping is an effective scaffold for the CKC process, there remains little systemic research supporting learning processes during CCM in interdisciplinary knowledge construction. This research investigates the effect of embedding an individual preparation phase prior to CCM, including the development of an individual concept map. The succeeding sections discuss theoretical arguments for and against an individual preparation phase.

Collaborative Concept Mapping with Individual Preparation Phase

Three main theoretical arguments for an individual preparatory phase are: 1) more room for personal reflection and development of an individual mental model; 2) better preparation for knowledge negotiation; and 3) more openness to the contributions of group members. CCM is a complex transformative process. An individual preparation phase allows individuals more room to reflect on the content and to develop ideas and arguments. Gao's [21] studies found that an individual preparation phase allows learners to organize their thoughts and present their ideas more effectively. Van Boxtel et al.'s [20] works on CCM showed that students with an individual preparation phase pose more questions than students without. Likewise, Teasley [15] posits that individuals could develop more coherent knowledge models to be understood in the collaborative work phase. Teasley's [15] introduced the concept of transactivity, that is the degree to which learners refer to and build on others' knowledge contributions. Weinberger and Fischer [23] claim that transactivity will determine the quality of the collaborative discourse in the knowledge co-construction process. They contend that 'integrated- and

conflict-oriented consensus building' statements in the social dimension of CKC would reflect a higher degree of transactivity whereas more externalization and elicitation statements point to a lower degree of transactivity [23]. Hence, embedding an individual preparation phase prior to collaborative concept mapping could make differences and obscurity within a group more detectable. This could possibly imply more focused discussions.

Collaborative Concept Mapping without Individual Preparation Phase

Theoretical arguments for CCM without an individual preparation phase are: 1) peer scaffolding; 2) prevents fragmented thinking; and 3) prevents defensive reasoning. Leaving out the individual preparation phase enables peers scaffolding from the start. Peer scaffolding is a temporary support provided by better students, which can enable individuals to execute complex tasks like concept mapping [24, 25, 26]. Another argument against an individual preparation phase is related to overcoming incoherency in CKC. For this reason continuous interaction is necessary because collaborative concept maps can be considered as cognitive systems, where all parts are interdependent, and collective action is more than the sum of the individual actions. [27,28], 'Collective action' is also believed to prevent defensive behavior and/or inclination to act independently [29]. In other words, individuals could be more open for each other's contributions. In the light of the differing theoretical groundings for with- and without individual preparation phase, we did not set up a directed hypothesis, but expected that the two conditions would yield differences on the interdisciplinary knowledge construction process during CCM. Our research question(s) are:

RQ 1. To what extent does with- or without-individual preparation phase (WIP & WOIP) affect the epistemic dimension of interdisciplinary knowledge construction in computer-assisted collaborative concept mapping?

RQ 2. To what extent does with- or without-individual preparation phase (WIP & WOIP) affect the social dimension of interdisciplinary knowledge construction in computer-assisted collaborative concept mapping?

2 Methodology

2.1 Sample and Design

A total of N=24 third year bachelor students, distributed among four groups of six (see Table 1) participated in a quasi-experimental field study. The groups were randomly assigned to one of the two experimental conditions (.WIP - with individual preparation phase and WOIP - without individual preparation phase). In each group students from different disciplines such as marketing, industrial engineering, multimedia design, Business IT and management, and computer science were represented.

Table 1. Participants in the experimental design with two conditions

	With Individual Preparation Phase (WIP)	Without Individual Preparation Phase (WOIP)
Gender		
Female	3	1
Male	9	11
	N=12 (2 groups)	N=12 (2 groups)

2.2 Learning Environment

Students worked on a collaborative assignment about macro trends using CCM. They first got a plenary lecture about macro trends, concept mapping and the opportunity to practice concept mapping and CmapTools [30]. Subsequently the WIP groups got 30 minutes to prepare an individual concept map before proceeding to CCM for 45 minutes. The WOIP groups started directly to create CCM for an hour and 15 minutes. Students in both conditions observed the same duration and undertook a similar task.

2.3 Data Analysis

To investigate the effects of the two experimental conditions on the epistemic and social dimension in the CCM process, data for analysis was derived from audio recordings of the collaborative discourse. Chi [31] proposes the use of semantic boundaries to determine a unit of analysis. Thus, each unit may contain one or more statements depending on the discussion threads, ideas and turn of talks. For the epistemic dimension, there was a total of 580 units of analysis for the WIP groups and 318 for the WOIP groups. For the social dimension, there was a total of 490 units of analysis for the WIP groups and 359 for the WOIP groups. The coding scheme for the

epistemic dimension is adapted from Beers et al. [1] where the collaborative discourse was coded with regard to: contribution, verification, clarification, elaboration, and positioning (see Table 2).

Table 2. Coding categories of the epistemic dimension (adapted from Beers et al., 2006)

Categories	Descriptor
Contribution	Surface an idea/ concept in which a new topic of conversation not discussed before is introduced
Verification	Request information about the intended meaning of a contribution
Clarification	React to a verification and/or seek further explanation to check for understanding
Elaboration	Expand an idea/ a concept by adding more information,
Positioning	Summarize one's viewpoint and take a position by agreeing, disagreeing, accepting or rejecting

Of equal significance is the analysis of the social dimension of the collaborative discourse during the CCM process. The five social modes of CKC imply the degree of transactivity and this inherently indicate the quality of the collaborative discourse [23]. Table 4 shows the five coding categories of the social dimension.

Table 4. Coding categories of the social dimension (Weinberger & Fischer, 2006)

Categories	Descriptor
Externalization	Contribute to discourse without any explicit or implicit references to previous contribution
Elicitation	Request information/ feedback from a learning partner
Quick consensus building	Accept a peer contribution without any modification
Integrated consensus building	Take over the perspective of their learning partners and/ or integrate different perspectives
Conflict-oriented consensus building	Reject and/ or repair contributions of their learning partners with further replacement, modification and/ or supplementation.

3 Findings

We first present the findings to RQ1. Figure 1 shows the means of the frequency of the occurrences of statements for both experimental conditions. Overall findings indicated that the WIP groups showed higher occurrences of statements for all categories in the epistemic dimension than the WOIP groups. Two distinguished differences lie in the occurrences of clarification and positioning statements. The WIP groups generated almost twice as many statements on clarification and positioning than the WOIP groups. These statements are instrumental in CKC and negotiation of shared meaning and understanding. The findings are best understood when examined against the findings to RQ 2 on effects of WIP and WOIP on the social modes of CKC in the succeeding segment.

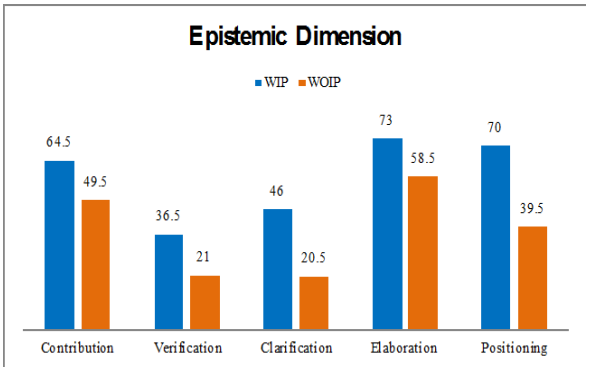

Fig. 1 Means of the five categories in the Epistemic mode of knowledge co-construction.

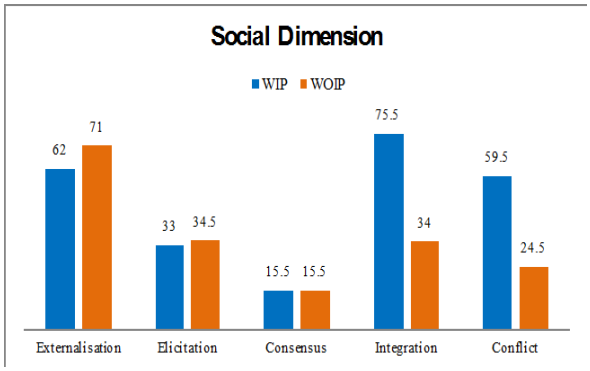

Fig. 2 Means of the five categories in the social mode of knowledge co-construction.
Note: Consensus = quick consensus building,
Integration = integrated-oriented consensus building,

Conflict = Conflict-oriented consensus building

Figure 2 shows the means of the frequency of the occurrences of statements in the social mode of knowledge co-construction for the two experimental conditions. The two groups in both conditions displayed almost similar tendency in eliciting contributions and ideas from peer, as well as in seeking quick consensus building. However, it is evident that there were more integrated- and conflict-oriented consensus building statements for the WIP groups, as compared to the WOIP groups. To arrive at integrated- and conflict-oriented consensus, verification, clarification and positioning statements play a pivotal role in establishing common grounds to converge at shared meaning and understanding. In seeking clarification, verifying claims and questioning positioning of perspectives, students would have to pose questions, query assumptions and re-evaluate contributions and ideas. This also explained why the two groups in the WIP witnessed more integrated and conflicted consensus statements in the course of negotiating shared knowledge. The findings on the social modes of the knowledge co-construction also illustrated the quality of the collaborative discourse. Higher occurrences of the integrated- and conflict-oriented consensus building indicated that there was more in-depth discourse for the two groups in the WIP condition which required them to explore and to consolidate the various perspectives and potential of the ideas and solutions in interdisciplinary thinking and the eventual knowledge co-construction

4. Discussion

This study investigates the effect of the WIP and WOIP conditions on the epistemic and social dimension of CKC during the CCM process. Overall descriptive statistics showed that the WIP groups were more engaged and more forthcoming with ideas: resulting in more in-depth discourse as exemplified by the higher occurrences of clarification, positioning statements in the epistemic dimension, as well as more integrated- and conflict-oriented building statements in the social modes of CKC. Our findings can be very cautiously interpreted as support for the necessity of individual preparation to enhance the CKC process. This could have provided students an essential 'personal' space to reflect on and to organize their thoughts and ideas. As evident in the findings, the WIP groups posed more question statements to seek verification and clarification. This aligns with Gao's [21] and van Boxtel et al.'s [20] findings that an individual preparation phase enabled the individuals to develop ideas and arguments more coherently and effectively at the collaborative level. In the social modes of knowledge co-construction, the WIP groups displayed more integrated- and conflict-oriented consensus building statements which indicates a higher level of transactivity [23]. Which is associated with greater knowledge integration [32]. In a similar fashion, Barron's [22] works also postulated that the quality of the collaborative discourse also carry significant bearings on the creation of "shared problem space". Negotiating common grounds in the shared problem space could have facilitated better quality of the CKC process in the WIP condition. The WOIP condition exemplifies the theory of peer scaffolding [24, 25]. As evident in the findings, there was higher occurrences of externalization and elicitation of contributions and ideas in the WOIP condition, as compared to the groups in WIP condition. Peer scaffolding accentuated the element of interdependency to achieve shared goals and provided individuals transitory support during the CKC process. On the same token, this transitory support by better students [25] prevented disjointed and fragmented thinking [27]. However, it could have also unwittingly impeded cognitive growth. Conflict is the source for cognitive growth and conceptual change [33]. Conflict consensus building is the underlying mechanism in the social co-construction of knowledge [23]. This could possibly explain the lower occurrences of conflict-oriented consensus building statements in the WOIP group, and thus, the lack of in-depth collaborative discourse in the interdisciplinary knowledge co-construction process. In the epistemic dimension, students in the WOIP condition were also less forthcoming with statements to seek clarification and to question positioning of peer's perspectives and ideas.

5. Conclusion and Future Work

The overall findings suggest that an individual preparation phase prior to CCM led to better interdisciplinary knowledge co-construction because it facilitates the grounding process where new knowledge is questioned, contended and verified. Learners need individual space to reflect, interpret and construct meaning to explore their own ideas and to think before talking. This could possibly explain the hidden efficacy of an individual preparation phase with individual concept maps before CCM. There was a higher level of transactivity in the WIP condition as evident by the higher occurrences of integrated and conflicted-oriented consensus building statements. Although we witnessed some interesting patterns in the epistemic and social dimension of the knowledge co-construction during the CCM process, we acknowledge that there are certainly inherent limitations in the attribution of effects in the two conditions (WIP & WOIP). One limitation could be the small sample size though qualitative analysis of all collaborative discourse for the four groups in the two conditions was carried out. The second limitation would be the integration of other disciplines whose cultural and social

practices differ with changing learning contexts. On the same note, more research on different learning settings and with different age range is needed to affirm that embedding an individual preparation phase prior to collaborative work might be instrumental to enhance the quality of the learning process and outcomes at the collaborative level. However, we are persuaded that the interesting findings from this research study has been insightful on how the sequencing of activities at different social levels might have an effect on the type and depth of collaborative discourse, the collaborative knowledge construction and interdisciplinary knowledge integration process. Likewise, it would be interesting to investigate how an individual phase prior to collaborative effort would impact the individual learning process and learning outcomes in future research.

References

1. Beers, P. J., Boshuizen, H. P., Kirschner, P. A., & Gijselaers, W. H.: Common ground, complex problems and decision making. Group Decision and Negotiation, vol. 15(6), 529–556 (2006).
2. Songer, N. B., & Linn, M. C.: How do students' views of science influence knowledge integration?. Journal of Research in Science Teaching, vol. 28(9), 761–784 (1991).
3. Roschelle, J., & Teasley, S. D.: The construction of shared knowledge in collaborative problem solving. In Computer supported collaborative learning, 69–97. Springer Berlin Heidelberg. (1995).
4. Roschelle, J., & Clancey, W. J.: Learning as social and neural. Educational Psychologist, 27(4), pp. 435–453. (1992).
5. Novak, J. D., & Cañas, A. J.: The origins of the concept mapping tool and the continuing evolution of the tool. Information visualization, 5(3), 175–184 (2006).
6. Engelmann, T., & Hesse, F. W.: How digital concept maps about the collaborators' knowledge and information influence computer-supported collaborative problem solving. International Journal of Computer-Supported Collaborative Learning, 5(3), 299–319 (2010).
7. Palincsar, A. S.: Social constructivist perspectives on teaching and learning. Annual review of psychology, 49(1), 345–375 (1998).
8. Scardamalia, M., & Bereiter, C.: Knowledge building. The Cambridge. (2006).
9. Hewitt, J., & Scardamalia, M.: Design principles for distributed knowledge building processes. Educational psychology review, 10(1), 75–96 (1998).
10. Vennix, J.: Group model-building: tackling messy problems. System Dynamics Review 15, 379–401 (1999).
11. Zwaal, W., & Otting, H.: The impact of concept mapping on the process of problem-based learning. Interdisciplinary Journal of problem-based learning, 6(1), 104–128 (2012).
12. Bromme, R., Rambow, R., & Nückles, M.: Expertise and estimating what other people know: The influence of professional experience and type of knowledge. Journal of experimental psychology: Applied, 7(4), 317–330 (2001).
13. Clark, H. H., & Brennan, S. E.: Grounding in communication. Perspectives on socially shared cognition, 13, 127–49 (1991).
14. Basque, J., & Lavoie, M. C.: Collaborative concept mapping in education: Major research trends. In: Proceedings of the Second International Conference on Concept Mapping, 79–86. Costa Rica, (2006)
15. Teasley, S. D.: The role of talk in children's peer collaborations. Developmental Psychology, 31(2), 207–220 (1995).
16. Stoyanova, N., & Kommers, P.: Concept mapping as a medium of shared cognition in computer-supported collaborative problem solving. Journal of Interactive Learning Research, 13(1), 111–133 (2002)
17. Schmid, R. F., McEwen, L. A., Locke, J., & De Simone, C.: Use of electronic concept mapping in organizing, analyzing and representing complex knowledge-based information. In American Educational Research Association Annual Meeting, New Orleans (2002).
18. Sizmur, S., & Osborne, J.: Learning processes and collaborative concept mapping. International Journal of Science Education, 19(10), 1117–1135 (1997).
19. Nesbit, J. C., & Adesope, O. O.: Learning with concept and knowledge maps: A meta-analysis. Review of educational research, 76(3), 413–448 (2006).
20. van Boxtel, C., van der Linden, J., Roelofs, E., & Erkens, G.: Collaborative concept mapping: Provoking and supporting meaningful discourse. Theory into practice, 41(1), 40–46 (2002)
21. Gao, H.: The effects of key concepts availability and individual preparation in the form of proposition formation in collaborative concept mapping on learning, problem solving, and learner attitudes. ProQuest Dissertations Publishing, Florida (2007).
22. Barron, B.: When smart groups fail. The Journal of the Learning Sciences, 12(3), 307–359 (2003)
23. Weinberger, A., & Fischer, F.: A framework to analyze argumentative knowledge construction in computer-supported collaborative learning. Computers & education, 46(1), 71–95, (2006).

24. Collins, A., Brown, J.S., & Newman, S.E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In: L. B. Resnick (ed.) *Knowing, learning, and instruction: Essays in honor of Robert Glaser,* pp. 453–494. Lawrence Erlbaum Associates, Hillsdale, NJ (1989).
25. Rogoff, B.: Apprenticeship in Thinking. Oxford, New York (1990).
26. Vygotsky, L. S.: Mind in society: The development of higher mental process. Harvard University Press, Cambridge (1978).
27. Senge, P.: The fifth discipline: The art and science of the learning organization. Currency Doubleday, New York (1990).
28. Baker, M., Hansen, T., Joiner, R., & Traum, D.: The role of grounding in collaborative learning tasks. Collaborative learning: Cognitive and computational approaches, pp. 31–63. (1999).
29. Argyris, C.: Education for leading-learning. Organizational dynamics, 21(3), pp. 5–17. (1993).
30. Cmap [Computer software]. (2017). Retrieved from http://cmap.ihmc.us/cmaptools
31. Chi, M. T.: Quantifying qualitative analyses of verbal data: A practical guide. The Journal of the Learning Sciences, 6(3), pp. 271–315 (1997).
32. Wen, M., Maki, K., Wang, X., Dow, S. P., Herbsleb, J., & Rose, C.: Transactivity as a Predictor of Future Collaborative Knowledge Integration in Team-Based Learning in Online Courses. In: Proceedings of the 9th International Conference on Educational Data Mining (2016).
33. Levine, J. M., Resnick, L. B., & Higgins, E. T.: Social foundations of cognition. Annual review of psychology, 44(1), pp. 585–612 (1993).