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MODESTUM

The Effects of a Collaborative Computer-based Concept Mapping Strategy on Geographic Science Performance in Junior High School Students

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ABSTRACT

This study explored the effects of a collaborative computer-based concept mapping strategy on Geographic Science learning outcomes in junior high school students. A quasi-experimental approach was applied to a sample of 85 9th grade students. Class instruction lasted for five weeks, with two classes each week. Using the quasi-experimental research approach, 27 students were assigned to a constructive activities group that received instruction without concept mapping assistance (NCM), 28 students were assigned to a group that received individual computer-based concept mapping (CBCM) assisted instruction, and 30 students were assigned to a group that received collaborative computer-based concept mapping (CCBCM) assisted instruction. We explored the impact of these methods of instruction on students' memorization, understanding, and application of concepts and on their higher order cognitive ability. The findings revealed that the CCBCM and CBCM groups scored better than the NCM group on the post-test. On the retention test, the CCBCM group outperformed the NCM group on all subtests.

Keywords: collaborative computer-based concept mapping, conception retention, geographic science learning

INTRODUCTION

The meaningful understanding and application of science has always been regarded as one of the most important objectives of science education. It is generally accepted that concept mapping plays a particular role in the

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State of the literature

- Concept mapping plays a particular role in learning.
- The use of concept mapping may not benefit all learners, and all types of targeted scientific literacy skills.
- Building concept maps in a collaborative environment may lead to greater learning and superior maps.

Contribution of this paper to the literature

- Previous collaborative concept mapping research has rarely investigated its effects on the different goals of science literacy.
- The use of a collaborative concept mapping may especially be beneficial to the topics with highly interdisciplinary and systematic characters.
- Combination of collaborative concept mapping strategy and student-centered instruction may produce better learning performance.

improvement of deeper learning in science classrooms (Aydin, Aydemir, Boz, Cetin-Dindar, & Bektas, 2009; Butler & Lumpe, 2008). Concept maps were first introduced by the psychologist Buzan (1974) as a radial thinking model (Buzan & Buzan, 1994). This approach is used to organize ideas and represent knowledge using keywords, tree structures and network diagrams, colors, and images. Concept mapping is a teaching and learning strategy that combines semantic understanding and creativity, and it involves thinking in terms of graphic representations (Karpicke & Blunt, 2011; Mutodi & Chigonga, 2016; Novak, 1990). Learners can create personal concept maps based on key content to reflect on their learning process and quickly recall the material using keywords. The use of symbols incorporates radial thinking, memorization techniques, and psychological information processing theory to help learners internalize knowledge and improve learning outcomes. Brinkmann (2003) described the following advantages of concept mapping during learning activities: (1) the open and flexible structure of concept mapping allows a free flow of ideas and the establishment of their connection to previous concepts; thus, knowledge management skills can be enhanced; (2) concept mapping accelerates the learning process and the memorization and recall of information and thus improves learning retention; (3) concept mapping can be used for the summarization and repetition of key points; (4) concept mapping can be composed in collaboration with others and, as a result, can improve learners' collaboration skills; (5) new concepts can be integrated into concept mapping; (6) concept mapping helps to represent and visualize learners' cognitive structures; (7) concept mapping can cultivate creativity.

However, the use of concept mapping may not benefit all learners. Several studies have reported no significant effects on learning by concept mapping or the combination of concept mapping with traditional instruction (Brandt et al., 2001; Pankratius & Keith, 1987). In a study of 180 high school students of a chemistry course, Stensvold & Wilson (1992) reported that there were no significant differences between students who constructed concept maps and those who did not. Stensvold & Wilson then argued that the lack of differences between the groups could be attributed to the differential interactions of individual students' abilities with the instructional technique.

The inconsistent results of these studies show that there is insufficient evidence to determine whether students who use concept mapping have better outcomes than students who do not. The lack of robust findings may be because concept mapping methods still need to be improved. First, it is difficult for students to draw and revise a traditional concept map using paper and pencil (Chang, Yeh, & Shih, 2016). Chang, Sung, & Chen (2001) indicated that a paper-and-pencil approach may suffer from the following limitations: (1) the approach is inconvenient for the interaction or communication between teachers and students over time, e.g., to provide appropriate feedback to students; (2) the maps are difficult to revise; and (3) the maps are complex and difficult to construct, especially when there is a lack of appropriate training and guidance. Second, in traditional concept mapping manipulation, students usually lack interdependence and are responsible only for themselves. Idea sharing and discussion are key components of classroom learning and may lead to better performance in a concept mapping approach. Third, the use of a concept map may not be beneficial to all types of targeted cognitive abilities in individuals. For example, concept mapping may especially benefit students' higher order cognitive abilities because concept mapping has been widely regarded as a metacognitive tool for science learning (Chang et al., 2016). The current study aimed to explore the effects of collaborative computer-based concept mapping on learning outcomes in junior high school geography students.

Computer-Based Concept Map Instruction for Learning

Compared with the traditional paper-and-pencil concept mapping approach, computer-based concept maps are more user-friendly and can be more easily corrected (Erdogan, 2009). The use of computer-based concept maps benefits teachers and learners due to the following characteristics: (1) ease of use and making corrections: nodes can be quickly added, corrected, and deleted in computer-based concept mapping, and, guided by simple instructions, users can adjust the concept map structure to make it more visually clear; (2) ease of communication with peers: learners can obtain clear information by displaying their concept maps on the screen and through discussion with others; (3) support for multiple resources: computer-based concept mapping can offer feedback, evaluation, and map history functions, as well as collaborative online tools for map composition (Chiou, Lee, Tien, & Wang, 2017). Therefore, computer-based concept mapping may compensate for weaknesses in traditional manual concept mapping. By applying concept mapping software as a supplementary tool, teachers can plan more effective teaching practices, have better insight into students' thinking processes, better understand students' difficulties, and provide timely remedial instruction.

Collaborative Concept Mapping Strategy

The widespread use of computer networks has changed the way we learn. Large amounts of information are being disseminated at faster speeds than ever before. The popularization of digital media has allowed for the development of new forms of learning activities, while innovative methods of information transfer have had a major impact on globalization. Learning about the acquisition of such new information via collaborative interaction has become a key competency fostered in educational activities. For example, the assessment of "collaborative problem-solving skills" was included in the survey conducted by the Program for International Student Assessment (PISA) for the first time in 2015. Collaborative skills have gradually been given more attention, leading to the establishment of teacher training platforms and the promotion of collaborative learning methods in different countries.

Collaborative learning has been regarded as a useful approach for learners to summarize and complete their conceptual structure via idea-sharing with peers. Numerous studies have supported the idea that collaborative learning is useful for developing high-order thinking skills, enhancing motivation, and improving interpersonal relationships (Johnson & Johnson, 2002; Slavin, 1991). In the collaborative learning environment, members of a small group are able to achieve more meaningful learning through discussion with peers. For example, learners can incorporate the thoughts, ideas, questions, and opinions of their peers into the field of their own interpretations and thus develop a more complete conceptual structure.

From the perspective of social constructivism, meaningful learning arises through a process of individuals interacting with their peers (Chai & Fan, 2016). Collaborative concept mapping strategies enable students to actively construct knowledge, brainstorm, and share ideas with group members. Furthermore, previous studies have revealed that a collaborative approach usually encourages motivation, attention, and engagement in students (Chiu, Jen, Chang, Lee, & Yeh, 2016; Daley & Torre, 2010; Gao, Shen, Losh, & Turner, 2007; Kwon & Cifuentes, 2009). Learners who are highly motivated to engage themselves also attain higher achievement. In our opinion, compared with self-constructed concept maps, collaborative concept mapping provides more opportunities for interaction and reflection among group members. In other words, building concept maps in a collaborative environment may lead to greater learning and superior maps.

Effects of Concept Mapping on the Development of Cognitive Abilities

There is insufficient evidence to determine whether the use of concept mapping is beneficial to particular types of targeted scientific literacy skills in individuals. Because concept mapping has been widely regarded as a metacognitive tool for science learning, concept mapping may especially benefit students' higher order abilities, such as conception application and problem solving. Chang et al. (2016) observed 61 9th grade physics students and revealed that a concept mapping approach effectively promoted higher order thinking and knowledge retention. On the other hand. Brandt (2001) argued that a concept mapping approach might sometimes complicate rather than facilitate knowledge acquisition. To the best of our knowledge, previous concept mapping research has rarely investigated its effects on the different goals of science literacy. This study attempted to fill this gap by conducting such an inquiry.

In summary, students must be able to filter large amounts of information, select the necessary knowledge, and organize it. Concept mapping may help students to organize/structure knowledge and facilitate metacognitive skills. A collaborative concept mapping strategy may further support idea-sharing and the refinement of concept understanding. In this study, three instructions were developed, including individual computer-based concept mapping assisted instruction, collaborative computer-based concept mapping assisted instruction, and instruction without concept mapping assistance. This study aimed to investigate the differences among these three methods of instruction on concept memorization, understanding, application, and higher order cognitive ability, both for immediate post-test and long-term retention.

METHODOLOGY

Research Design and Procedures

The data collection consisted of two phases: (1) administration of different instructions and (2) evaluation of students' performance at post-test and retention-test. During the first phase, students were assigned to instruction without concept mapping assistance (NCM), individual computer-based concept mapping (CBCM) assisted instruction, and collaborative computer-based concept mapping (CCBCM) assisted instruction groups. The experiment was followed by an immediate post-test to investigate the respective impact of the different instruction strategies on immediate performance and a one-month delayed post-test to determine their impact on long-term performance.

Participants

In total, 85 9th grade students from a public senior high school located in the northern region of Taiwan participated in this study. Using a quasi-experimental research approach, 27 students were assigned to the NCM group, 30 students were assigned to the CBCM group, and 28 students were assigned to the CCBCM group. The three groups were judged to have similar knowledge of geographic science, as they did not differ significantly in their academic performance in geographic science during the previous semester ($F = 1.70$, $p > 0.05$).

Design of the Instruction

The course "Geographic Science - European" covers six subunits: land and ocean, climate, population, industrial activity, resources, and environments. The course length is five weeks, with two lessons per week and 45 minutes per lesson.

The students in the CBCM and CCBCM groups were asked to create a concept map after each unit, whereas the students in the NCB group were asked to take notes and reflect on the content. Students in CCBCM group were divided into heterogeneous groups of two to three members. Group members had to create concept maps collaboratively.

To help the students familiarize themselves with the concept mapping tools, the CBCM and CCBCM group students first had two lessons to learn how to create concept maps using Xmind software. In this course, students

Figure 1. Xmind operation interface

learned how to represent a concept map with pencil and paper as well as on a computer. The teachers helped students' families with the necessary components for creating a concept map, including depCBCMion, links (lines), linking words, appropriate fonts, and image use. A scaffolding strategy was adopted to reduce students' anxiety that may have resulted from unfamiliarity with concept mapping: (1) major concept identification; (2) using linking words to describe the relationships among the main concepts; (3) sub-concept identification; (4) using linking words to describe the relations among the sub-concepts; and (5) a concept map review.

The NCM course content was similar; however, instead of concept mapping, the NCM group adopted note-taking and reflection. A scaffolding strategy was adopted to teach the students how to take notes: (1) identify the topic sentences in the article; (2) identify the main point of the article; and (3) create a summary by deletion, generalization, and rewriting.

Concept Mapping Tool

Xmind (http://www.xmind.net) is an easy-to-use tool (more than 1 million users) for creating concept maps developed by Xmind Ltd. (Beel, Langer, Genzmehr, & Gipp, 2014). **Figure 1** shows the simple Xmind Chinese user interface. Xmind allows students to easily establish a relationship between two concepts or plots on the map. The summary and presentation function helps students to reflect and interact with peers. Because the Xmind server (Online Mind Map Library) has been used worldwide, users can share their concept maps and exchange ideas through the platform.

Learning Performance Instruments

To measure student learning performance concerning concept memorization, understanding, application, and higher order cognitive ability, we constructed and developed the "Geographic Science - European" Conception Test (GSECT). The GSECT is a 40-question multiple-choice test. A panel of specialists, including two university professors and three high school teachers, established the content validity of the GSECT. These specialists checked the degree of alignment of the test items with the important concepts that were introduced in the Geographic Science - European curriculum. The reliability coefficient was estimated to be 0.91 for a 148-person sample using the Kuder–Richardson formula 20 (KR-20). **Table 1** illustrates examples of the items on the GSECT.

Table 1. Examples of the contents of the "Geographic Science - European" conception test

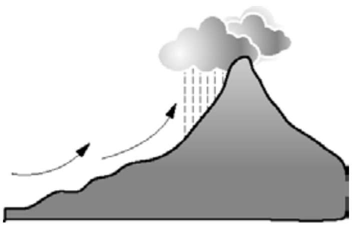
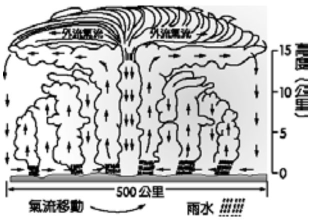
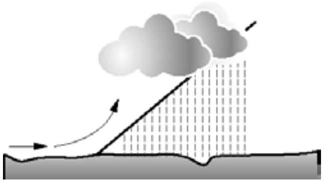
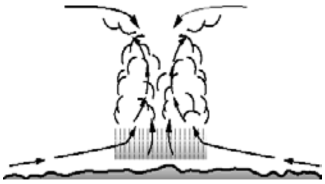
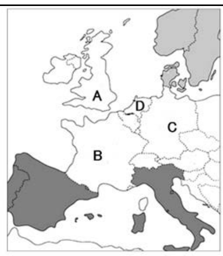
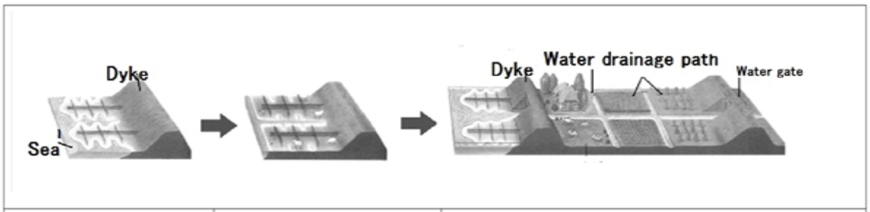
Category	Number of items	Example
Conception Memorization	17	"Rotterdam is located at the mouth of a large river which connects to North Atlantic shipping lanes. It is the largest commercial port in the Netherlands, and with the development of transit trade, it has become a large European gateway for import and export via the ocean and is referred to as the window into Europe." Which river is the "large river" mentioned in the text above? (A) Danube (B) Rhine (C) Seine (D) River Thames
Conception Understanding	7	Mountain ranges on the Scandinavian Peninsula tyically run north-south and experience high precipitation on their western sections. What is the main type of rainfall that they experience? (A)  (B)  (C)  (D) 
Conception Application	6	The figure below shows the method by which one country increased its land area. Where on the map is this country? (A) A (B) B (C) C (D) D   1.Dyke, Sea, Fence made from wood and iron wire on the coastal mud and sand. 2. More mud and sand is collected around the fence for green grass later. 3. Entrance: During the ebb tide, the water gate is opened to drain off water. The fence is then constructed further on the coastal beach and another low-lying paddy field is added. Dykes are built and water gates are made in many places. During the rising tide, the water gates are closed in order to prevent seawater from entering.
Higher Order Cognitive Ability	10	Japan and Norway are both major fishery countries. The natural environment of these two countries share many similarities. Which of the following are advantages that both of these countries share: (A) coastal landforms mainly formed by cliffs, wide harbors, and deep water; (B) coastal currents and rich fishery resources; (C) many mountains and few flatlands; (D) surrounded by the sea; (E) rich coal and iron resources, and developed shipbuilding industries. (A) ABC (B) BCD (C) CDE (D) ADE

Table 2. A comparison of learning performance for three types of instruction in post-test

	Instruction	Mean(SD)	*F* (ANOVA)	Effect Size (*f*)	Scheffe test
Conceptual Memorization	NCB (1)	7.89 (3.51)	9.51*	0.48	(2)>(1) (3)>(1)
	CBCM (2)	10.10 (2.98)			
	CCBCM (3)	11.25 (2.05)			
Conceptual Understanding	NCB (1)	4.59 (2.27)	11.71**	0.53	(3)>(2) (3)>(1) (2)>(1)
	CBCM (2)	5.57 (1.50)			
	CCBCM (3)	6.68 (0.61)			
Conceptual Application	NCB (1)	2.63 (1.36)	17.83**	0.66	(2)>(1) (3)>(1)
	CBCM (2)	3.93 (1.23)			
	CCBCM (3)	4.43 (0.79)			
Higher Order Cognitive Ability	NCB (1)	4.07 (2.42)	13.45**	0.44	(2)>(1) (3)>(1)
	CBCM (2)	5.57 (2.24)			
	CCBCM (3)	6.39 (1.91)			

(1)=NCB (instruction without concept mapping assistance)
(2)=CBCM (individual computer-based concept mapping assisted instruction)
(3)=CCBCM (collaborative computer-based concept mapping assisted instruction) * $p < 0.05$; ** $p < 0.01$

Data Analysis

The major independent variable in this study was the format of the instructions (NCB, CBCM, and CCBCM), and the dependent variables were related to student concept memorization, understanding, application, and higher order cognitive ability regarding the Geographic Science – European curriculum. A univariate analysis of variance (ANOVA) was conducted to analyze how the students' conceptual understandings were affected by the instructions, with post-test and retention test scores as the dependent variable. To meet contemporary calls for improvement in the interpretation and reporting of quantitative research in education (Rennie, 1998), this study reports practical significance along with each statistical significance test. The effect size index *f* was used, because it is more appropriate for the analysis of variance or covariance (Cohen, 1988). According to Cohen's rough characterization, $f = 0.1$ is deemed to be a small effect size, $f = 0.25$ a medium effect size, and $f = 0.4$ a large effect size. The assumptions used for the ANOVA and the inferential statistical analyses were tested using SPSS version 22.0.

RESULTS

Effects of Computer-Based Concept Mapping Instruction on the Post-Test

As shown in **Table 2**, the ANOVA analysis revealed significant main effects in the post-test for concept memorization ($F = 9.51$, $p < 0.001$, $f = 0.48$, large effect size), understanding ($F = 11.71$, $p < 0.001$, $f = 0.53$, large effect size), application ($F = 17.83$, $p < 0.001$, $f = 0.66$, large effect size), and higher order cognitive ability ($F = 7.85$, $p < 0.001$, $f = 0.44$, large effect size). A post-hoc test (Scheffe) indicated that the students in CCBCM and CBCM groups outperformed the NCM group in concept memorization, understanding, application, and higher order cognitive ability scores.

Effects of Computer-Based Concept Mapping Instruction on the Retention Test

As shown in **Table 3**, the ANOVA analysis revealed significant main effects in the retention test for concept memorization ($F = 13.01$, $p < 0.001$, $f = 0.56$, large effect size), understanding ($F = 12.81$, $p < 0.001$, $f = 0.55$, large effect size), application ($F = 10.51$, $p < 0.001$, $f = 0.51$, large effect size), and higher order cognitive ability ($F = 10.04$, $p < 0.001$, $f = 0.50$, large effect size). A post-hoc test (Scheffe) indicated that the students in the CCBCM outperformed the NCM group in concept memorization, understanding, application, and higher order cognitive ability scores.

Table 3. A comparison of learning performance for three types of instruction in retention-test

	Instruction	Mean(SD)	*F* (ANOVA)	Effect Size (*f*)	Scheffe test
Conceptual Memorization	NCB (1)	7.93 (3.93)	13.01**	0.56	(3)>(1)
	CBCM (2)	9.93 (4.03)			
	CCBCM (3)	12.57 (1.60)			
Conceptual Understanding	NCB (1)	4.30 (2.25)	12.81**	0.55	(3)>(2)
	CBCM (2)	5.13 (2.10)			
	CCBCM (3)	6.71 (0.53)			(3)>(1)
Conceptual Application	NCB (1)	2.96 (1.56)	10.51**	0.51	(3)>(1)
	CBCM (2)	3.77 (1.45)			
	CCBCM (3)	4.61 (0.88)			
Higher Order Cognitive Ability	NCB (1)	4.67 (2.97)	10.04**	0.50	(3)>(1)
	CBCM (2)	6.07 (2.30)			
	CCBCM (3)	7.50 (1.58)			

(1)=NCB (instruction without concept mapping assistance)
(2)=CBCM (individual computer-based concept mapping assisted instruction)
(3)=CCBCM (collaborative computer-based concept mapping assisted instruction) * $p < 0.05$; ** $p < 0.01$

DISCUSSION

The present study compared the relative effectiveness of collaborative computer-based concept mapping assisted instruction, individual computer-based concept mapping assisted instruction, and no computer-based concept mapping assisted instruction during a "Geographic Science - European" high school course. We explored the impact of the different methods of instruction on student concept memorization, understanding, application, and higher order cognitive ability. The findings revealed that the CCBCM and CBCM groups scored better than the NCM group on the post-test in all four dimensions. On the retention test, the CCBCM group outperformed the NCM group on all subtests.

In traditional computer-based concept mapping, the learners have to independently construct, plan, and coordinate concepts and branches between them and constantly monitor and link previous knowledge by revising the map. The process of defining and systematizing concepts and constructing the relationships among concepts may conform to Ausubel's requirements for meaningful learning (Ausubel, 1977). Chang et al. (2016) concluded that concept mapping tools can provide the following benefits: (1) constructing concept maps can facilitate cognitive representations of a specific topic (Derbentseva, Safayeni, & Canas, 2007; Didis, Ozcan, & Azar, 2014). (2) the metacognitive process triggered by constructing concept maps may promote deeper understanding and the development of higher order cognitive abilities compared with instructions that do not involve a concept mapping strategy.

Johnson and Johnson (1989) concluded that interactive discussion is a key factor in the development of higher order cognitive strategies in collaborative learning. First, the process of interaction with peers for solving problems via collaboration can increase learning motivation and thus results in better memorization and deeper understanding of learning topics (Järvelä & Järvenoja, 2011). Furthermore, the presentation process allows students to retrieve their memory, summarize, and restructure their conceptions, thus enhancing their performance (Chang, Yeh, & Barufaldi, 2010). Moreover, by receiving feedback from peers in a group, students can enrich their learning experience, develop multiple perspectives, and reinforce their own cognitive structure (Eden, 2004). Finally, according to the behavioral theory of learning motivation, students' motivations can be reinforced via the rewards obtained through group achievement.

One month after the experiment, the same performance test was given to measure the level of retention in four types of knowledge. This study found that collaborative computer-based concept mapping assisted instruction effectively promoted knowledge retention. The CCBCM group outperformed the NCM group on all subtests of the retention test. This finding may help us to better understand the effects of collaborative computer-based concept mapping assisted instruction on cognitive abilities. Previous studies concerning the effects of concept mapping on learning performance have tended to use an immediate post-instruction outcome construct to evaluate learner achievement, rarely investigating its effects on long-term retention. (Brandt et al., 2001; Stensvold & Wilson, 1992). The present results indicate that the collaborative computer-based concept mapping learning environment contributed to the retention of all four types of knowledge more effectively than did traditional classroom instruction.

As mentioned by Jonassen (2000), learning requires forming links between existing knowledge and new knowledge to comprehend information. The collaborative computer-based concept mapping assisted instruction provided a basis for those principles/environments; students were thus able to effectively construct cognitive structures (map) by forming links between their existing and new knowledge while interacting with peers and then establishing meaningful understanding of the concepts. Zollo and Winter (2002) indicated that knowledge retention is usually caused by knowledge evaluation, analysis, and distillation, which are key components of a collaborative computer-based concept mapping strategy (Zollo & Winter, 2002). Furthermore, a collaborative computer-based concept mapping strategy may serve as a scaffold because it is intended to help students develop more refined, integrated, and structured knowledge frameworks (Poehler & Prediger, 2015).

We speculate that the use of a collaborative concept mapping may especially be beneficial to the topics and subjects with highly interdisciplinary and systematic characters. Previous studies also revealed collaborative concept mapping may not always benefit for all subjects (Ledger, 2003; Suthers, 2001). For example, Ledger (2003) indicated that CCM may not have significant effect on improving student' attitudes and declarative knowledge. Basque and Lavoie (2006) indicated that more interactions and more elaborated interactions lead to better high-level cognitive performance. From a cognitive load perspective, in collaborative learning environment, collaborating learners can gain from each other's working memory capacity during learning, and access more cognitive resources than when working individually (Paas & Sweller, 2012). Students in collaborative concept mapping environment could have induced lower cognitive load and may acquire more cognitive resources for higher order thinking. It would be interesting to conduct a sequence of experiments to observe the effects of collaborative concept mapping on instruction in specific. The use of collaborative concept mapping may provide the necessary framework for students to integrate and organize interdisciplinary knowledge.

In the last decades, student-centered approach have been strongly advocated by science educators and researchers due to its profound influences in contemporary science education (Hsiao et al., 2014; Yeh, Huang, Chan, & Chang, 2016). These instructional strategies, such as learning cycle, inquiry approaches, and Science, technology, engineering and mathematics (STEM) learning, have been widely demonstrated to have effectiveness in promoting students' learning. Rather than having a student's learning being directly transmitted by teachers, from the perspective of student-centered approaches, an individual learner's cognitive structure regarding a specific topic must be actively constructed by the learner. Such a self-construction practice supports the development of higher order thinking skills which students need when solving daily problems. As mentioned previously, the finding of this study reveals that collaborative computer-based concept mapping strategy is useful for fostering students' higher order cognitive ability, echoes the goal of student-centered approaches. Furthermore, concept mapping strategy encourages students to reflect on their knowledge in order to representing cognitive structure. This meta-cognition process also enable students to actively integrate interdisciplinary information. We can observe that aforementioned effects of concept mapping is in line with the purpose for STEM education. Therefore, we believe that the combination of collaborative concept mapping strategy and student-centered instruction will produce better learning performance.

Implications and Limitations

In recent years, teachers and researchers have generally acknowledged that concept mapping plays a fundamental role in fostering deep learning. The result of this study revealed that collaborative computer-based concept mapping might be an effective strategy for enhancing student conception understanding and metacognition. Future studies should explore strategies of the collaborative environment setting. In a collaborative learning environment, how to divide the learners into optimal teams, how to train students' social skills, and how to foster supportive interactions between group members could be important issues. It would be of interest to perform hypothesis testing regarding the effect of collaborative concept mapping for different achievement learners. Furthermore, the small- to middle-sample size in this study highlights not only the need to generalize results with caution, but also the need for further replicate studies in this area of research. We thought it would also be interesting for additional investigations to analyze the impact of interaction between collaboration and concept mapping strategies with an enlarged, represented sample size to give more reliable results.

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