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Empirical study on the effects of social network–supported group concept mapping

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Abstract

Social networks provide traditional concept mapping of new opportunities for concept construction with grouping, social interaction, and collaborative functions. However, little effort has been made to explore the effects of social network–supported concept mapping compared with traditional individual concept construction. This paper explores the effects of social network–supported group concept mapping (SCM) activity and compares them with the effects of individual concept mapping (ICM) activity. A platform named CoCoing.info (<http://cocoing.info>) is utilized to examine the SCM and ICM activities under three studies, which drove the following research questions: (1) Do map structure (i.e., propositions, hierarchies, examples, cross-links, and scores) and mapping activity (i.e., map modification period and frequency) differ between ICM and SCM in students on specialized courses? (2) Do map structure and mapping activity differ between ICM and SCM in students on general education courses? (3) What are the effects of group size on SCM? In study I, four classes are selected to ensure a strong social network learning environment control. On the basis of study I, study II extends the controlled environment within an open social networking environment with a total of 1106 SCM maps and 569 ICM maps to produce an improved overview of concept mapping. The findings of studies I and II are consistent, demonstrating that the students constructed more comprehensive concept maps and had a higher modification period and frequency with SCM than with ICM, which indicates that in a social network learning environment, SCM is favorable to ICM. Study III considers each participant's contributions to identify an optimal group number. The results of study III indicate that groups with two to seven members perform better than larger groups. Overall, the findings demonstrate the benefits of integrating concept mapping with social networking for student learning outcomes.

Keywords: Social networking, Concept mapping, Technology-supported learning environment, Data analytics

Introduction

A concept map—a network graph comprising a main idea and various nodes and links—is a useful and effective tool for illustrating students' implicit knowledge of a specific subject (Brown, 2003; Novak, Gowin, & Bob, 1984). Concept mapping is also used in various knowledge creation and modeling fields, such as web-based information-seeking activities (Chu, Hwang, & Liang, 2014), instructional design (Hwang, Yang, & Wang, 2013), and computer-based knowledge assessment (Weinerth, Koenig, Brunner, & Martin, 2014). Originally, computer-supported concept maps were constructed and manipulated by individual learners, and no collaborative or peer group activity was involved because of technological limitations. This type of concept mapping activity was classified as individual concept mapping (ICM). However, with the development of information and communications technology, groups of users can now edit a shared file remotely (Basque & Lavoie, 2006; Chiu, Huang, & Chang, 2000). This development makes the learning activity more group-centric, interactive, and dynamic, and students are now able to build knowledge through peer connections.

Technology has broadly changed the nature of concept mapping activity from individualized to collaborative. Various studies have highlighted the differences between them and the advantages inherent in the shift toward collaborative mapping on the basis of the perspectives of student achievement, motivation, engagement, and other factors (Kwon & Cifuentes, 2009; Meenderink, 2018). Collaborative concept mapping benefits from collaborations on a specific concept map and discussions among friends. However, according to Kwon and Cifuentes (2007), the composition of students in groups can lead collaborative concept mapping to have a negative influence on student achievement and rapport during student cooperation. In its further investigation, the outcomes concluded that a disciplined and supported collaborative working environment is necessary and essential for collaborative group, especially a learning environment with technical support and social atmosphere (Chiu, Wu, & Huang, 2000). Similar results were reported by Holmes (2019), who found that student-selected groups enhance knowledge sharing and communication to overcome their individual differences, whereas researcher-selected groups are prone to frustration with unequal role assignments and have negative effects on peer interaction. The students in student-selected groups reported that they knew they could perform well because of the friendships. In other words, the social influences of peers encourage and conducive interaction support group member's learning. Moreover, the students had strong attitudes toward the size of their respective groupings. This is also in line with the works of Akcaoglu and Lee (2016) and Strijbos, Martens, and Jochems (2004) that reported the relation between group size and peer interaction. While technology-supported collaborative concept mapping has gained increasing attention, the related research of social influences on concept mapping is still limited.

Currently, social network platforms promote collaborative concept mapping in a new and more advanced area, giving students more opportunities to work together (Smirnov & Thurner, 2017). Social network plays a critical role of connecting learning partners and facilitating social interaction (Haythornthwaite et al., 2018). The social support and knowledge sharing enabled by these platforms enhance students' knowledge construction by enabling them to perceive and negotiate individual differences in knowledge (Blikstad-Balas, 2016; Idris & Ghani, 2012; Yampinij, Sangsuwan, & Chuathong, 2012).

According to Gao, Luo, and Zhang (2012), the survey revealed the potential for using social networking applications to encourage collaborative learning in various educational settings (Blikstad-Balas, 2016; Idris & Ghani, 2012; Yampinij et al., 2012). This development has made social network–supported group concept mapping (SCM) activities possible. However, the effects of social networks on collaborative concept mapping remain unclear. Examining the innovative combination approach might assist with the design of SCM learning activities. Therefore, an empirical study exploring the effects of SCM is worthwhile.

Little research has been conducted on SCM, which has led to a gap in the understanding of SCM applications and their effects. For this reason, the focus of this study is on evaluating the differences and relationship between ICM and SCM. CoCoing.info (<https://cocoing.info>), a social networking platform on which students can engage in ICM and SCM simultaneously, was utilized for this purpose. Because a concept map is composed of a concept map structure and concept mapping task, these factors should be prioritized in its assessment (McClure, Sonak, & Suen, 1999). Accordingly, three studies are proposed to examine the effects of ICM and SCM. First, student-generated ICM and SCM features are compared through the examination of map structure (i.e., propositions, hierarchies, examples, cross-links, and scores) and mapping activity (i.e., modification period and frequency) to determine whether SCM can significantly enhance student knowledge construction compared with ICM. Second, from the perspective of educational big data analysis, the analysis scale is extended and the ICM and SCM effects displayed by the students on CoCoing.info are investigated. Third, the social factors (group size and group member contributions) are explored to determine the appropriate group size for SCM for improved learning experiments, knowledge construction performance, and SCM activity design. Accordingly, the following research questions are addressed in this study:

1. Do map structure and mapping activity differ between ICM and SCM in students on specialized courses?
2. Do map structure and mapping activity differ between ICM and SCM in students on general courses?
3. What are the effects of group size on SCM?

Related work

To examine the unresearched area of SCM, the essential aspects of technology-supported concept mapping, collaborative concept mapping, and social network–supported collaborative learning were reviewed. The literature review of each aspect is detailed in the following section.

Technology-supported concept mapping

A concept map consists of the concepts within a specific knowledge domain and the meaningful connections between those concepts, and it provides a visualization of the knowledge structure of the given concepts (Novak, 2010). A concept map is a teaching and learning tool that combines deep thinking, reflection, and creativity (Chang et al., 2017). During the concept mapping process, students must organize and structure units

or segments of cognition to create new knowledge (Sun & Chen, 2016). In addition, a concept map allows free creation and provides flexibility for idea expansion and generation. From a cognitive constructivist perspective, concept mapping produces new knowledge by compiling human-made constructions (Ruiz-Primo, 2004). Concept maps are useful for education and learning, including knowledge creation (Farrokhnia, Pijeira-Díaz, Noroozi, & Hatami, 2019), concept structure visualization and meaning representation (Novak, 1990, 2010), assessment, and misconception identification (Lin, Chang, Hou, & Wu, 2016; Tseng, Chang, Rundgren, & Rundgren, 2010; Watson, Pelkey, Noyes, & Rodgers, 2016).

With the rapid growth of novel technology, researchers have focused on technology-supported concept mapping. Accordingly, more educational software has been developed and adopted to facilitate concept mapping and improve related activities. For example, Liu, Kim, and Wang (2018) developed a collaborative concept mapping system called ConceptScape that aimed to externalize users' reflections on videos. ConceptScape consists of two main functions, a web-based video player and an editable and interactive concept map canvas, that allows users to watch a video and promote their reflection simultaneously. In addition, a node provides a time anchor link to a specific concept in the video, in which users can effectively discover the video based on the concept-based navigation. For online collaborative concept mapping, the design of crowdsourcing workflow included three stages, concept and timestamp generation, concept linking, and link labeling, which supported users contributing concepts parallel in each stage. The results showed that ConceptScape is a helpful tool for video learning, major concept providing, and collaborative concept map generation. Similarly, Cañas et al. (2004) presented CmapTools, a web-based system, to support individual and collaborative concept map construction and sharing through the Internet. The concept map construction module provides the functions that users can build nodes and links and change the styles (fonts, colors, and lines). Associated resources (images, videos, audios, URLs, and texts) can also be included in the map. The collection module allows users to save the concept map in either user's computer or a server. The servers provide the collaborative concept mapping environment where online users can asynchronously/synchronously construct concept maps, post comments, discuss, and promote peer review. CmapTools has been widely used in various educational contexts for over 15 years (Selevičienė & Burksaitienė, 2016). It is also regarded as a beneficial concept mapping software for higher education. Islim (2018) applied the iPad application BaiBoard HD, an online concept map drawing tool, to assist real-time collaborative concept mapping activities. The application enabled users easily add, delete, label, reorganize the nodes and links, and promote group discussion of map content. The students were asked to collaborate face-to-face while creating the concept maps during class time. All users can observe the evolving map and directly modify the content on their own tablet. To conclude, collaborative concept mapping previously was applied as face-to-face, web-based pedagogical strategies, or small group interaction in traditional classroom settings (Liu et al., 2018). However, no efforts have been put on organizing large-scale social network learners into a collaborative concept map construction, let alone social network-supported group concept mapping.

Moreover, concept maps have been integrated with various types of educational technology. Dias, Hadjileontiadou, Diniz, and Hadjileontiadis (2017) demonstrated that the

integration of concept maps with Moodle positively affects concept map construction and enhances interactions during concept mapping. Lin et al. (2016) integrated Google Docs into collaborative concept mapping and compared the effects with a paper–pencil approach to record students' learning achievements, concept representation, and attitudes. The findings indicated that Google Docs concept mapping more effectively promotes concept representation and collaboration than the paper–pencil approach does. Sun and Chen (2016) integrated dynamic concept mapping with an interactive response system and found that the integration approach significantly enhances students' learning self-efficacy and learning achievement. Undoubtedly, the technology-supported concept mapping approach has gained considerable attention and yields fruitful results contributing to the variation and richness of concept mapping approaches.

In short, technology-supported concept mapping can be useful as an educational strategy to promote meaningful knowledge creation and stimulate student sharing, communication, and interaction. Nevertheless, little information is available on the integration of concept maps with modern social network applications, creating room for further discussion. This study aims to fill this gap in the research.

Collaborative concept mapping

With the support of information and communications technology, students can discuss ideas with their peers and collaboratively construct concept maps (Coutinho, 2009). Independent and collaborative work are recognized as distinct strategies in education (Meenderink, 2018). Individual learning emphasizes a task-oriented process, self-monitoring, purposeful activities, and independent decision making and problem solving with personal responsibility. By contrast, collaborative learning focuses on group-oriented work, achieving a mutual goal, sharing personal opinions and differences, compromising with peers, and supporting teammates with shared responsibility. Collaborative learning has been identified as offering many more benefits than individual learning. For example, students can learn from new perspectives and their peers' feedback, they are supported in developing a shared understanding, and they must discuss their own ideas with their peers to achieve a mutual goal.

Group size has been stated as key aspect in collaborative learning and has the effects on peer and individual learning performance (Melero Merino, Hernández Leo, & Manathunga, 2015) as well as participation (Kim, 2013; Shaw, 2013). Riahi and Pourdana (2017) investigated the effects of small group of collaborative concept mapping and individual concept mapping on English as a foreign language learners' reading comprehension. They suggested that the composition of the groups and the group size might be factors that influence the effects of collaborative concept mapping due to no statistical differences between the two strategies were found, and groups of five might work the best. A similar argument was also made by Chang et al. (2017), who indicated that team assignment, group member interaction, and group composition are crucial aspects concerning collaborative concept mapping, and small group can develop more meaningful learning via peer interaction and discussion. According to Holmes (2019), students had strong attitudes related to the size of their respective groupings. They believed that small group size with two to five is better, and three was the maximum preferred. In short, collaborative concept mapping requires a high level of social

processing, discourse, and cognitive demands for a learner to continually construct new understanding from others and bridge different ideas to reach shared knowledge (De Weerd, Tan, & Stoyanov, 2017). In short, the issue of group size and member interaction has been widely discussed that is able to affect the collaborative concept mapping. However, no effort has put the attention on the effects of group size on collaborative concept mapping under social network settings. Therefore, the research gap sheds the light on this study.

Social network-supported collaborative learning

Social networking technology can be helpful that simplifies the process of managing a large sharing network and relationships, exchanging person-to-person and group messages, and promoting the co-creation of content both within and outside the classroom (Al-Rahmi, Othman, & Yusuf, 2015; Coutinho, 2009; Greenhow & Askari, 2017; Lampe, Wohn, Vitak, Ellison, & Wash, 2011; Scardamalia & Bereiter, 2014). However, studies of collaborative concept mapping were more focusing on face-to-face and web-based pedagogical strategies in small groups in traditional classroom settings, let alone social network-supported group concept mapping. While sharing and communication have been regarded as important elements in collaborative concept mapping (Islim, 2018), the effects of how social network-supported group concept mapping is still unknown. Therefore, insight into how social networking is able to support concept mapping activities can therefore be valuable.

Social networking tools have been proved that can support a distributed and networked process of knowledge building via social web and connection (Manca & Ranieri, 2016; Mnkandla & Minnaar, 2017). Social network building plays a critical role of connecting learning partners and facilitating social interaction (Haythornthwaite et al., 2018). According to Gao et al. (2012), the survey revealed the potential for using social networking applications to encourage collaborative learning in various educational settings, such as conference, K-12, and higher education. Moreover, instant message sharing on social network platforms has led to empirical findings that can facilitate idea sharing, support negotiation, scaffold collaborative knowledge building, and maintain social connections with peers (Chen & Huang, 2019; Fields, Lai, Gibbs, Kirk, & Vermunt, 2016). Clearly, social networking platforms and the supportive functions are widely applied and effectively promoting collaboration practices. However, more research is needed to understand the research gap of social network-supported group concept mapping and probe its possible causes.

In this vein, SCM seems feasible for providing learners with representations of their cognitive structures to share with other learners through social network building. In contrast to collaborative concept mapping, SCM has the potential to enhance learning interaction between peers and teachers from various backgrounds and extend the scope of knowledge sharing and construction. More specifically, SCM might be able to facilitate the organization of various friendships and working groups, foster social consensus among all group members, and permit face-to-face and online interactions at a distance. Therefore, to fill these research gaps, the current study considers the effects of SCM compared with those of ICM from the perspectives of map construction, collaborative settings, and educational strategies. The authors developed a technology-

supported concept mapping environment called CoCoing.info and implemented the system in the experiment. The details of the system are discussed in the next section.

ICM and SCM social networking platform: CoCoing.info

Currently, most social networking applications focus on sharing life events with users’ friends rather than fostering the sharing of ideas and concept construction (Lewis, Pea, & Rosen, 2010). An appropriate design for a social network learning environment is necessary for successful learning. From the perspective of system design, dedicated application integration is essential for providing various learning resources and ensuring the integrity of learning activities.

To investigate the effects of concept mapping, the authors designed a social networking platform named CoCoing.info (<https://cocoing.info>), an open platform that was introduced online in February 2016. As depicted in Fig. 1, three utilities—social network building, concept map construction, and instant message sharing—were implemented. The utilities are described in the following sections.

Social network building

The social network–building tool facilitates student creation of peer relationships on CoCoing.info, which is an essential function for SCM. Figure 2 displays the interface. Two types of social relationships—individual friends and groups—can be created to support SCM collaboration and concept map sharing. Individual friend relationships

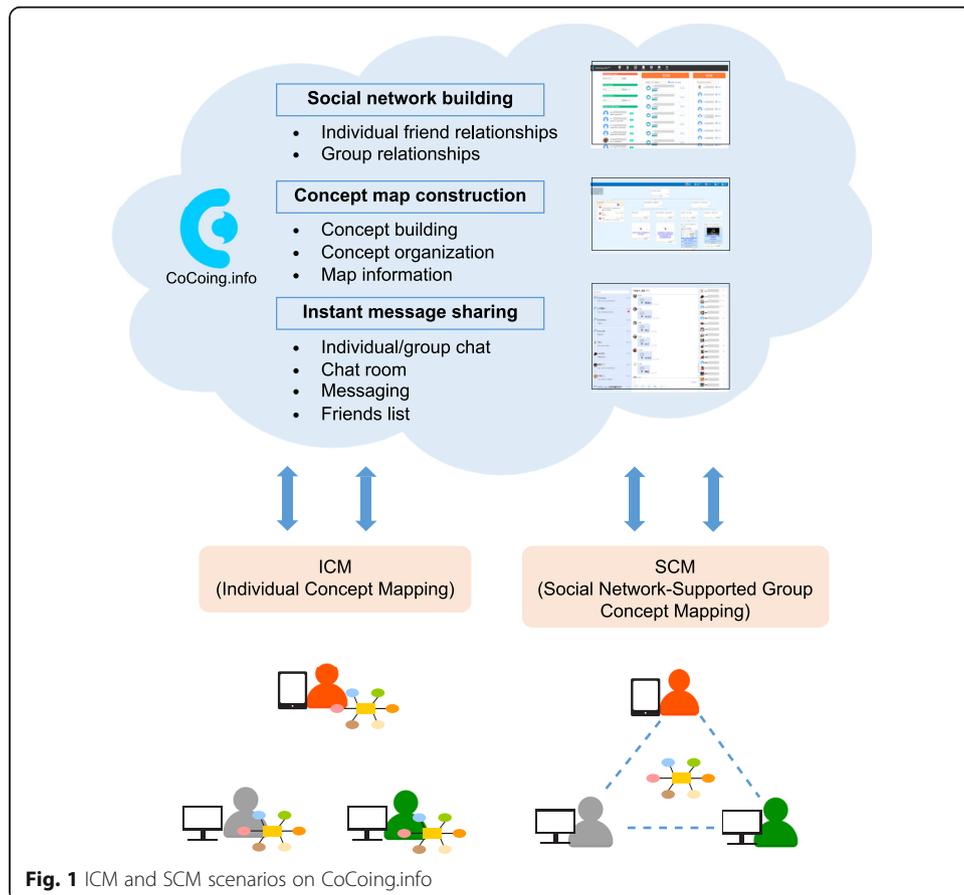


Fig. 1 ICM and SCM scenarios on CoCoing.info

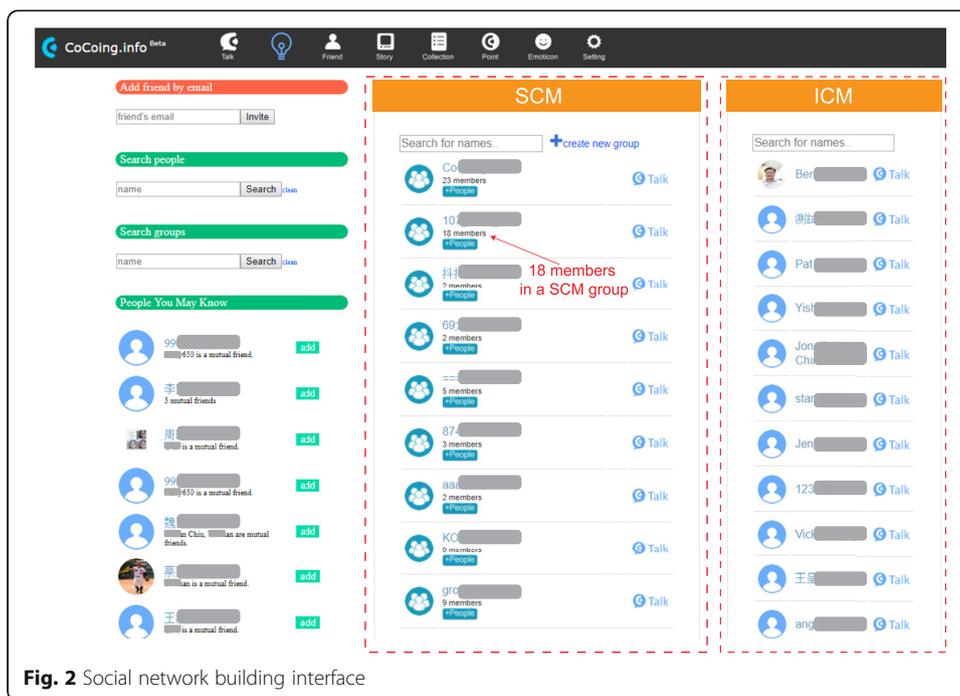


Fig. 2 Social network building interface

allow students to create peer-to-peer and peer-to-teacher friendships and exchange ideas and knowledge directly, and group relationships make learning activities more collaborative and socially oriented with many-to-many connections that students can establish to share their knowledge. The establishment of individual friend relationships and group relationships on CoCoing.info is described in the following sections.

Individual friend relationships

To establish individual relationships, students can befriend people by e-mail or by searching for their username. The system also identifies and recommends mutual friends to facilitate relationship building. Friend usernames and profile pictures are listed on the ICM panel (Fig. 2). Clicking on a friend’s profile allows the user to share instant messages or concept maps with them.

Group relationships

To create a group relationship, students can join an established SCM group or form a new group with their friends. Groups are shown on the SCM panel with their names, pictures, and number of members. By clicking on a group profile, the user can share instant messages or concept maps with the group.

Concept map construction

As shown in Fig. 3, the concept map construction tool provides assistance with concept mapping through several functions. The three main functions are concept building, concept organization, and map information. The tool allows students to create a concept map simultaneously and synchronize the concept map during its construction while sharing it with peers and teachers.

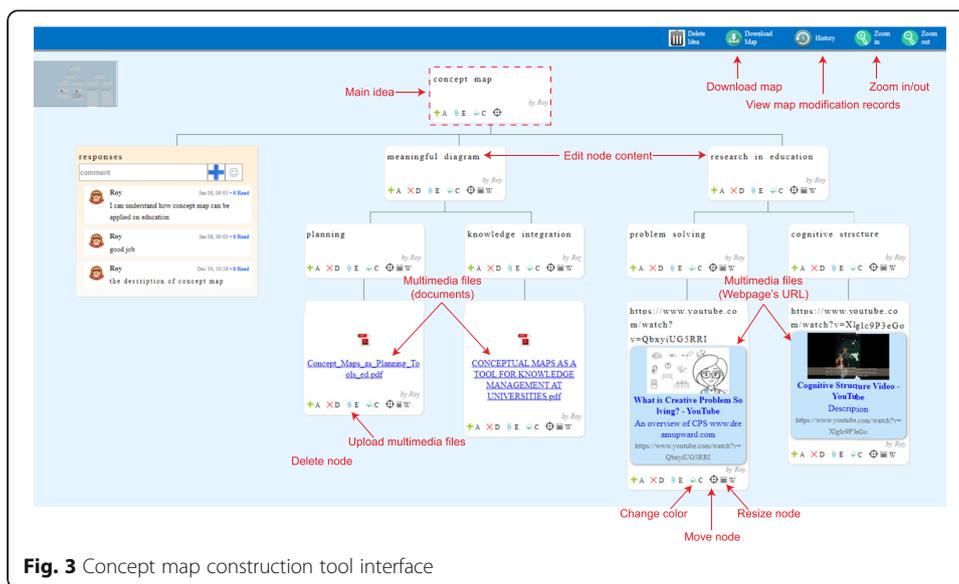


Fig. 3 Concept map construction tool interface

Concept building

The concept-building tool has five subfunctions: add node, delete node, edit node content, upload multimedia files (i.e., images, videos, and documents), and attach a URL. These subfunctions enable students to sketch a concept map individually and collaboratively. The multimedia files and webpage links allow students to add supplementary information and learning materials to make concepts more vivid. The CoCoing.info social network platform enables students to create, edit, and modify their individual and group concept maps at any time and place.

Concept organization

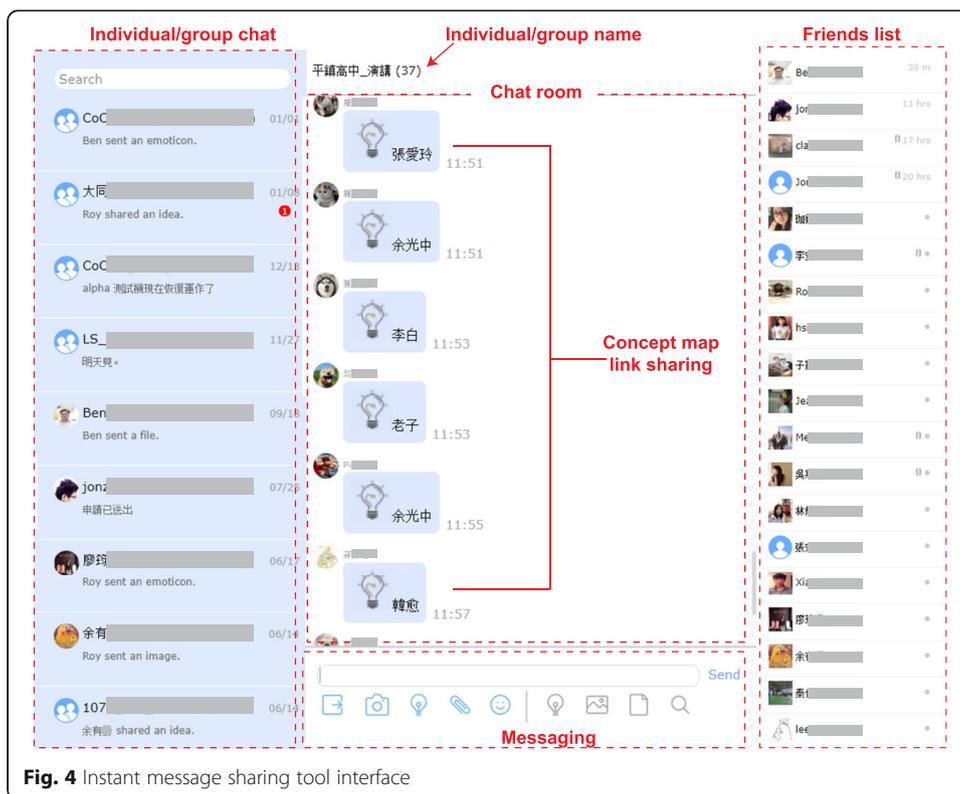
The concept organization tool has three subfunctions: move node, resize node, and change node color. These allow students to reshape a concept map during the concept-building stage. With this function, students can easily classify concepts using different colors and move concepts separately and as groups. A concept overview window assists students in organizing concept maps efficiently.

Map information

The map information tool has four subfunctions: zoom in/out, view map modification records, download map, and view peer responses. Students can review the history of the map and peer feedback. During the SCM stage, students can interact and exchange ideas through the peer response subfunction to cooperate on tasks. The function enhances concept map portability and knowledge construction.

Instant message sharing

To achieve the goals of discussion and knowledge sharing in SCM, the instant message sharing tool was designed, the aims being to offer an improved concept mapping experience and learning activity design, and to facilitate student data collection and analysis. The instant message sharing tool (displayed in Fig. 4) has four subfunctions:



create individual/group chats, join chat rooms, send messages, and view friends lists. It encourages map sharing both in and outside the classroom by allowing synchronous communication in SCM.

Individual/group chat

The individual/group chat subfunction lists friends and groups by their usernames and pictures, most recent messages, and timestamps. Students receive notifications of messages as red bubbles indicating the number of unread messages.

Chat room

The chat room subfunction displays the user’s message history with individuals and groups. Each message contains the sender’s name and picture, the message content, and a timestamp. Figure 4 illustrates concept map link sharing in a chat room. The links are displayed with the image of a lightbulb and the title of the map. Clicking on a link takes the user to the concept map construction tool.

Messaging

The messaging subfunction allows students to share with friends and groups in the chat room multimedia messages, including plain text messages, images, concept maps, and documents (Microsoft Word, Excel, and PowerPoint documents and PDFs). Students can upload materials from personal devices such as PCs, tablets, and smartphones. Messages can also be forwarded to other individuals or groups to facilitate SCM construction and discussion.

Friends list

The friends list subfunction shows the online status of the user’s friends. Friends’ profiles display their username, picture, an icon of their login device, and the time of their most recent login. Friends who are currently online are identified at the top of the list with a green mark.

Evaluation

Because a concept map is composed of a concept map structure and concept mapping task, its assessment should focus on these two factors (McClure et al., 1999). Accordingly, three studies were designed to investigate ICM and SCM from the perspectives of map construction, mapping activities, and collaborative settings. Each study was conducted to answer the corresponding research questions. Study I compared ICM and SCM in terms of map structure and activity in a controlled environment. On the basis of study I, study II extends the controlled environment within an open social networking environment to produce an improved overview of concept mapping. Study III measured the effect of group size on SCM. An encoding method was adopted to deidentify all personal information, such as usernames, in this experiment. To elaborate on the research methods of this experiment as well as the relations among the three studies more clearly, Fig. 5 was provided.

Study I: map structure and mapping activity in ICM and SCM in specialized courses

Participants and research context of study I

Seventy-two preservice teachers were enrolled in the same subject titled “teaching with technology” taught by the same teacher in the four classes at a university’s center for teacher education completed study I. The four classes had similar class size between 15 and 20 learners. The study I was designed as a controlled environment with limited participants, same subject, and fixed classes. The average age of participants was 23.72 years, and 41 were male and 31 were female. The participants were guided through the

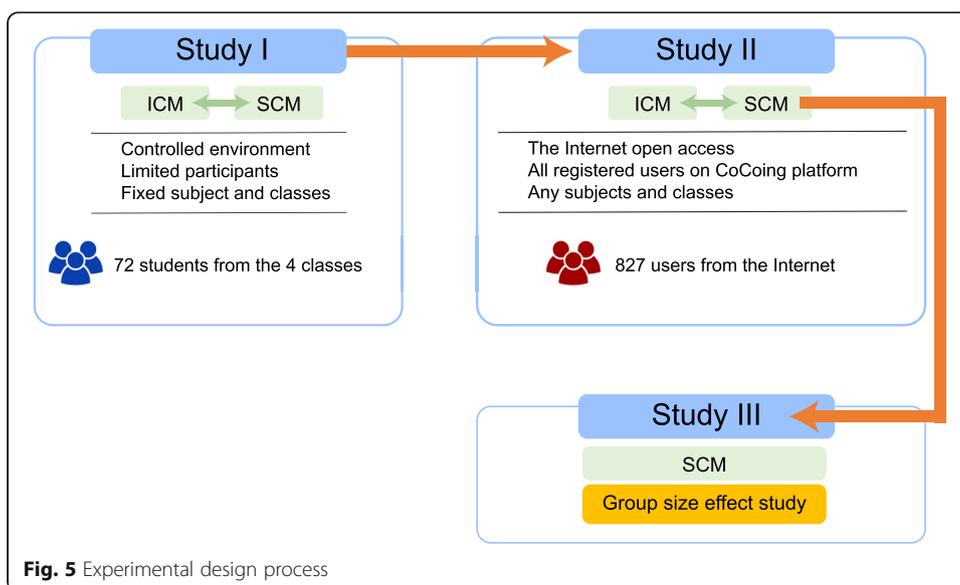


Fig. 5 Experimental design process

process of registering on the system and practiced using the system for the first week of their courses. The seventy-two students were asked for the ICM and SCM construction at the conclusion of each courses according to the learning activity design, where the concept map being built was related to the learning topics and content. The assignments were conducted in class and could be accomplished during or after the class.

Data selection of study I

According to the system design, students were asked to select the type of concept map at the beginning of the map creation process. Therefore, the ICM and SCM categories were identified automatically. Accordingly, a total of 263 ICM maps and 159 SCM maps were created by the 72 participants and selected as the analysis sources of study I. The concept map data were cataloged as map structure and mapping activity. The map structure data comprised propositions, hierarchies, cross-links, and examples. The mapping activity data comprised map creation and modification timestamps to enable the calculation of modification periods and frequencies.

To visualize ICM and SCM, social network analysis and the analysis tool UCINET SNA (Borgatti, Everett, & Freeman, 2002) were implemented to identify students' access to concept maps on the basis of indegree centrality. Figure 6 illustrates a portion of access networks between concept maps and students, where students are represented as blue squares and maps as orange triangles. For example, the connections of S1940 (student ID 1940) → C3121 (concept map ID 3121) and S2114 → C3358 were identified as ICMs because the indegree of the concept map was 1. By contrast, the connections among S2057, S705, S2097, and C3311 were identified as SCM because the indegree of their concept map was greater than 1.

Instruments of study I

Concept map has been used to develop and evaluate student's knowledge structure via the four main components including propositions, hierarchy, cross-links, and examples (Maker & Zimmerman, 2020; Novak et al., 1984). The scoring criteria of concept map components has been applied in many studies for many purposes, for example, measuring students' understanding (Erdimez, Tan, & Zimmerman, 2017), assessing students' achievement level, and tracking the improvement of students' comprehension of concept relationships (Tan, Erdimez, & Zimmerman, 2017). The scoring results can reveal how students organize concepts at different level of hierarchy, how many concepts students can demonstrate in a map of the domain, how students identify the relationships among concepts, and how many examples students can include to present their ideas (Maker & Zimmerman, 2020). Researchers have found that the scoring criteria (Novak et al., 1984) is convenient for quick scoring (Tan et al., 2017). Therefore, due to the research scale in the experiment, we adopted the scoring criteria of concept map components to match the purpose appropriately.

The scoring rubric awards points for concepts and relationships in maps, and the sum of the points represents the map score. The scoring rubric was applied in the present study to evaluate ICM and SCM, and the criteria and weighting are described in Table 1. To achieve the goal of automatic concept map assessment by CoCoing.info, all calculations and procedures were completed in Python using

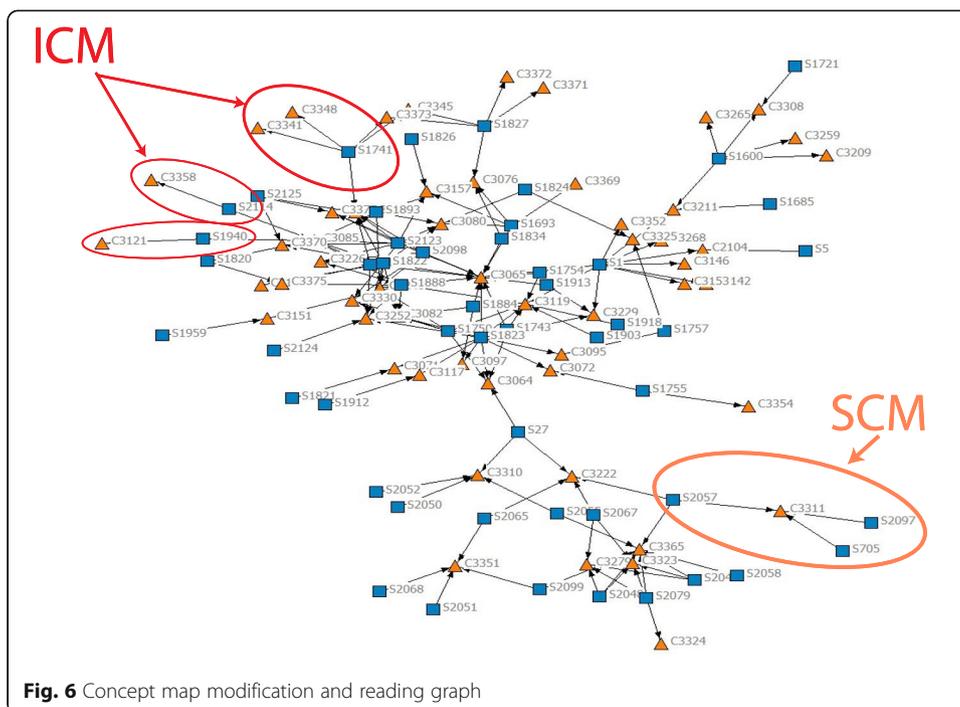


Fig. 6 Concept map modification and reading graph

MySQL databases. The pseudocodes for concept map structure evaluation are described in Table 2.

To measure mapping activity in ICM and SCM, modification period and frequency data were collected. The period between the map creation timestamp and last modification timestamp was used as the modification period. Modification frequency was determined using map modification timestamps.

Results of study I

Descriptive statistics and independent *t* tests revealed the data patterns and differences between ICM and SCM. Table 3 displays the descriptive statistical results that means and standard deviations are listed for each item, and categorized by map structure and mapping activity. The average (mean) ICM map comprised 6.98 propositions, 2.58 hierarchies, 0.17 examples, and 0.41 cross-links and was awarded a score of 20.04. SCM maps had an average of 22.94 propositions, 3.72 hierarchies, 1.20 examples, and 4.00 cross-links and a score of 42.72 points.

According to the results of independent *t* tests, SCM maps contained significantly more propositions ($t = -6.94, p < .001$), hierarchies ($t = -7.02, p < .001$), examples ($t = -2.94, p < .001$), and cross-links ($t = -4.42, p < .001$) than did ICM maps. In addition,

Table 1 Criteria for concept map scoring

Object	Point	Description
Proposition	1	A line and link indicates the relationship between two concepts
Hierarchy	5	A valid hierarchical layer level
Cross-link	2	A valid connection between two segments of a concept
Example	1	A file, image, or webpage link in a concept

Table 2 Pseudocodes for concept map structure evaluation

Line	Pseudocode
1	For i = concept map ID 1 to ID n
2	Proposition = select count (proposition) from proposition table where concept map ID = i
3	Hierarchy = select max (layer) from concept map table where concept map ID = i
4	Cross-link = select count (link) from crosslink table where concept map ID = i
5	Example = select count (example) from example table where concept map ID = i
6	Score = Proposition+ Hierarchy*5+ Cross-link*2+ Example
7	Save the score into the concept map table

SCM outscored ICM ($t = -7.47, p < .001$). This finding reveals that building concept maps with social support results in more complex maps and higher levels of knowledge construction.

With regard to mapping activity, students spent an average of 85.88 min constructing an ICM map but 325.05 min on an SCM map. More interestingly, ICM maps were modified an average of 6.32 times, whereas SCM maps were modified an average of 35.67 times. The results of independent t tests demonstrated that SCM had a longer modification period and a higher modification frequency than ICM. This suggests that students were more engaged in SCM than in ICM.

Discussion of study I

The results of the map structure analysis demonstrate that SCM maps tend to contain more propositions, hierarchies, examples, and cross-links and receive higher scores than ICM maps. This is the first experiment to provide clear evidence that SCM can significantly promote learners' knowledge construction with the support of social network interaction compared with ICM. This finding is consistent with that reported by Novak (2010), who indicated that a concept map is a promising tool when combined with collaborative activity for inducing meaningful learning and knowledge reconstruction. Collaboration and sharing in concept mapping can trigger the active integration of reflective thoughts within a work group, especially in a social network environment (Jena, 2012). Forms of social support such as interaction, communication, and encouragement potentially facilitate the knowledge

Table 3 Descriptive statistics and independent t test results for concept map structure and activity

Items	ICM mean (SD)	SCM mean (SD)	t
Map structure			
Propositions	6.98 (12.33)	22.94 (27.35)	-6.94 ***
Hierarchies	2.58 (1.14)	3.72 (1.84)	-7.02 ***
Examples	0.17 (0.80)	1.20 (4.33)	-2.94 ***
Cross-links	0.41 (2.29)	4.00 (10.09)	-4.42 ***
Scores	20.04 (16.89)	42.72 (35.94)	-7.47 ***
Mapping activity			
Modification period (min)	85.88 (286.51)	325.05 (464.00)	-5.86 ***
Modification frequency	6.32 (34.75)	35.67 (62.32)	-5.45 ***

*** $p < .001$

building of students with common sharing recognition and information from groupmates (Chang et al., 2017). This finding also agrees with that of Scardamalia and Bereiter (2014), who noted that the use of social networking technology enhances knowledge construction, peer interaction and sharing, and teamwork effectiveness. According to the results, SCM can be a useful concept mapping approach and process of building knowledge in a social network environment.

Significant differences were found in terms of map modification period and frequency, which indicates that students invested more time and had a greater construction frequency for SCM than ICM. Basque and Lavoie (2006) found that students creating a collaborative concept map spent 36–120 min on average per session, whereas students partaking in SCM devoted more time (325 min) to mapping activities in this study. This finding is also consistent with that of Engelmann and Hesse (2010), who reported that students in a collaborative concept mapping group spent more time on mapping activities and created more comprehensive and larger concept maps compared with the individual group. Students in the collaborative mapping group required more construction time because of their conversations in the learning environment pertaining to the concept map (Meenderink, 2018). In addition, the time spent by the team creating the collaborative concept map helped members to clarify purposes and roles and build motivation and mutual trust (Danaher & Midgley, 2013). The findings of the current study reveal that compared with ICM, SCM requires a longer map modification period and higher map modification frequency, which enables learners to continually develop a strong structure for a concept map.

Study II: map structure and mapping activity in ICM and SCM among general education students

Participants of study II

Representing the accurate public and general effects of ICM and SCM among the students on CoCoing.info is particularly important for the improvement of concept mapping design. During the period from February 2016 to January 2019, 827 undergraduate and graduate students between the ages of 18 and 26 years participated in concept mapping construction activity on CoCoing.info. The students were guided through the process of registering with the system and practiced using the system during the first week of their courses. The course activities included ICM and SCM. The participants were assigned to build ICM or SCM maps at the conclusion of each course, where the concept map being built was related to their learning topics and content. On the basis of study I, study II extends the controlled environment within an open social networking environment to produce an improved overview of concept mapping.

Data selection of study II

A total of 569 ICM maps and 1106 SCM maps were created by 827 participants in study II. For analysis, the concept map data were cataloged according to whether they pertained to structure or activity. The map structure data comprised propositions, hierarchies, cross-links, and examples. The mapping activity data comprised map creation and modification timestamps to enable the calculation of modification periods and frequencies.

Results of study II

Table 4 displays the descriptive statistical results. The average (mean) ICM map comprised 27.19 propositions, 4.44 hierarchies, 0.09 examples, and 1.97 cross-links and was awarded a score of 49.46. SCM maps had an average of 46.53 propositions, 4.92 hierarchies, 0.39 examples, 2.07 cross-links, and a score of 71.54 points.

According to the results of independent t tests, SCM maps contained significantly more propositions ($t = -6.37, p < .001$), hierarchies ($t = -4.23, p < .001$), and examples ($t = -4.18, p < .001$). In addition, SCM outscored ICM ($t = -6.57, p < .001$). This finding reveals that building concept maps with social support results in more complex maps and higher levels of knowledge construction.

With regard to mapping activity, students spent an average of 250 min constructing an ICM map but 447 min on an SCM map. More notably, ICM maps were modified an average of 74 times, whereas SCM maps were modified an average of 129 times. The results of independent t tests demonstrate that SCM had a longer modification period and higher modification frequency than ICM. This suggests that students were more engaged in SCM than in ICM.

Discussion of study II

Because social network sites enable students to become more connected with one another (Bond, Chykina, & Jones, 2017), endeavoring to better understand the overall effects and dynamics of SCM is crucial and urgent. Study II reveals the effects and differences between ICM and SCM from a public perspective on a big data scale. The results are consistent with those of study I, revealing that students construct more comprehensive concept maps and have a higher modification period and frequency for SCM than ICM. The findings of studies I and II confirm the consistent effects of ICM and SCM, which broadly match students in general on CoCoing.info. In addition, the results suggest that concept map construction may be natural for students on CoCoing.info. Study II presents a practical suggestion for future studies to deploy SCM on a large scale and evaluate social network-supported learning and student works. To further investigate the involvement of learners in SCM construction, the next study focuses on verifying the group effects on SCM contribution.

Table 4 Descriptive statistics and independent t test results for concept map structure and activity

Items	ICM mean (SD)	SCM mean (SD)	t
Map structure			
Propositions	27.19 (35.10)	46.53 (88.36)	-6.37 ***
Hierarchies	4.44 (2.13)	4.92 (2.40)	-4.23 ***
Examples	0.09 (0.60)	0.39 (2.24)	-4.18 ***
Cross-links	1.97 (4.93)	2.07 (4.97)	-0.38
Scores	49.46 (41.28)	71.54 (95.70)	-6.57 ***
Mapping activity			
Modification period (min)	249.53 (403.61)	447.25 (487.53)	-4.28 ***
Modification frequency	74.00 (132.08)	129.09 (187.48)	-7.45 ***

*** $p < .001$

As the report in study II, the SCM group had significantly higher mean scores of the six dependent variables than the ICM group. However, we also found that the standard deviation of each variable in the SCM group was also higher than the ICM group. The findings indicated that although a SCM was constructed by more than one student but the structure performance of concept map were also unstable on such mapping activity. On the other word, a concept map that created collaboratively might have the influence toward the stability of outcome.

Studies I and II had been found the consistent results that SCM group had higher mean scores of the six dependent variables than ICM group. Nevertheless, based on the research design, study I was focused on a controlled experiment environment that had fixed subject, classes, and limited participants. On the contrary, study II was hold in an open access environment that involved any users, subjects, classes, and various backgrounds. It can be speculated that, on the Internet, an open access learning environment can potentially enhance students' concept map construction, especially in SCM group. Meanwhile, it also shows the facts that an open access online learning environment might promote students but we also found that the standard deviation scores of the six variables in study II were higher than study I. These findings can be a useful guideline of how to design an appropriate open access learning environment in general perspectives that is able to maintain students' leaning performance.

Study III: effects of group size on SCM

Data selection of study III

SCM group size and map scores were collected from the same data source used in study II (1106 SCM maps created by 827 participants). The average SCM score for each group size and the average member contribution score were calculated. The main elements and calculation methods were as follows:

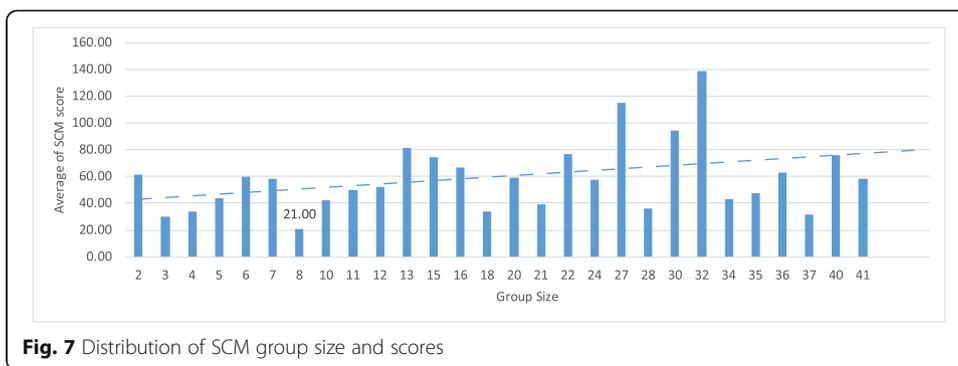
$$\begin{aligned} \text{Let } n &= \text{total number of SCM in each group size} \\ \text{Average SCM score} &= \frac{\sum_{i=1}^n \text{SCM score}_i}{n} \\ \text{Average member contribution score} &= \frac{\text{average of SCM score}}{\text{group size}} \end{aligned}$$

Instruments of study III

Study III was dedicated to determining the effects of group size on SCM by measuring the tendencies of and correlations between group size and average SCM scores. A bar chart was employed to elaborate on the distribution of group size and scores. In addition, a line chart was used to report member contributions. To reveal the tendencies of and correlations between SCM group size and scores, a Pearson correlation analysis was conducted on the selected data.

Results of study III

Figure 7 presents a chart on the distribution of group size and SCM map scores. Group size is indicated on the x -axis; the smallest group had 2 members, and the largest had 44. The y -axis displays the average SCM scores; the lowest was 21, and the highest was 147. The result of the Pearson correlation analysis revealed a moderate correlation



between group size and score, with a correlation coefficient of .37. The pattern demonstrates that SCM map scores increase with group size. This finding confirms that group size influences SCM map scores.

Although Fig. 7 illustrates a tendency for group size to influence SCM scores, it does not clarify student contributions. Figure 8 depicts the distribution of group size and the number of points per group member. The *x*-axis indicates group size. The *y*-axis reports the points; the lowest score was 0.86, and the highest was 30.76. As can be observed in Fig. 8, groups with two members had the highest member-to-score ratio. Groups with three to seven members also received more contributions from members than other group sizes.

Discussion of study III

The results of study III reveal that group size can positively influence concept map scores in SCM, which is consistent with the findings reported by Pfister and Mühlpfordt (2002) that group size is a determinant of learning performance. The composition and number of members of each group have also been identified as factors that influence the effect of collaboration on concept mapping (Riahi & Pourdana, 2017). The Pearson correlation analysis in Fig. 7 shows a positive tendency between SCM score and group size. This finding agrees with Pfister and Oehl (2009) that outcomes improve as group size increases in collaborative learning. It can be inferred that shared understanding and individual group members’ knowledge can enhance the performance of knowledge coconstruction (Farrokhnia et al., 2019). Therefore, the results of study III indicate that student grouping in SCM is an important component that not only



affects map editing and idea representation but also the structure of concept maps drawn through member collaboration and group knowledge externalization. Moreover, social network platforms promote collaborative concept mapping activities in a new and advanced area in which students have more opportunities to work with friends from different backgrounds (Smirnov & Thurner, 2017). From this sociocognitive viewpoint, these platforms also facilitate increased interaction and networking among students and partners and the cocreation of content (Greenhow & Askari, 2017). Such social network–supported group concept mapping design has demonstrated its feasibility and is valuable for enhancing student grouping performance during concept mapping.

From the perspective of member contributions to SCM, the results indicate that two to seven people is the appropriate group size for SCM. A large group size during concept mapping may reduce students' involvement and performance as a result of intense social interaction with other members. This speculation is consistent with the conclusion drawn by Chang et al. (2017), who suggested that small groups can evoke more meaningful learning through peer discussion and idea sharing. Students in small groups have more opportunities for interaction and reflection among group members. Kim, Yang, and Tsai (2005) found that studies on group size in collaborative concept mapping generally focus on either dyads or triads because small group sizes can provide an appropriate learning environment for students to exchange their ideas, coconstruct knowledge, and provide efficient social support. The results of study III provide evidence that the optimal SCM group size is between two and seven learners, which is the optimal range for student contributions to concept map construction.

Conclusions

Compared with traditional ICM activities, social networking technology has demonstrated superiority with respect to its potential for use in more social, open, and collaborative construction of concept maps. To explore the effects of social networking on concept mapping, an SCM approach was developed and the CoCoing.info social networking platform was set up in this study to support students in both SCM and ICM activities.

Three studies were conducted to address the research questions. Overall, our work sheds light on experimental findings that (1) on map structure, SCM is better than ICM whatever in controlled (study I) or open environment (study II), but students spend more time developing SCM maps and modify them more frequently; (2) both ICM and SCM performed higher scores on map structure and mapping activity in the open environment (study II) than in the control environment (study I), but students also presented higher standard deviations in the open environment (study II) than in the control environment (study I); (3) a positive correlation between SCM group size and map score was found, and when group member contributions are considered, a group size of between two and seven people is ideal for SCM construction.

The empirical research described in this paper highlights the importance of understanding SCM and its advantages and limitations. However, the scale of the study was limited. Future work should consider other dimensions. Even though SCM was found to be beneficial, student performance in group concept mapping is also determined by

factors such as group communication skills, learning and organizational skills, and attitudes toward SCM. We also suggest to the future works that the qualitative assessment should be included to evaluate concept map and to explore from various perspectives. This study examined SCM factors in terms of map structure, SCM modification period, SCM modification frequency, and SCM group size. Other SCM and social interaction factors should be considered in future work.

Abbreviations

C3121: Concept map identification number 3121; C3311: Concept map identification number 3311; C3358: Concept map identification number 3358; ICM: Individual concept mapping; ID: Identity; Min: Minute; PC: Personal computer; PDF: Portable document format; S1940: Student identification number 1940; S2057: Student identification number 2057; S2097: Student identification number 2097; S2114: Student identification number 2114; S705: Student identification number 705; SCM: Social network-supported group concept mapping; SD: Standard deviation; SNA: Social network analysis; URL: Uniform resource locator

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Authors' contributions

The authors read and approved the final manuscript.

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Availability of data and materials

The data cannot be made publicly available due to legal restrictions imposed by the government of Taiwan in relation to the "Personal Information Protection Act".

Competing interests

The authors declare that they have no competing interests.

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