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Lanqin Zheng

Knowledge Building and Regulation in Computer-Supported Collaborative Learning

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Foreword

Many years ago, individual learning was the motto of learning. However, since computers and networks appeared, more and more attention has been paid to these for learning and social interactions. Consequently, collaborative learning has become the main strain of learning in the field of education. So far, collaborative learning has been widely adopted in elementary, secondary, and higher education.

With the development of technology, a new field of computer-supported collaborative learning (CSCL) emerged. Perhaps a major concern of CSCL centers on how people learn together via computers. Furthermore, the core value of CSCL focuses on human growth and development through co-constructing knowledge, skills, emotions, attitudes, and values. However, participants have to regulate themselves during collaborative learning due to various conflicts of cognitions, emotions, attitudes, and behaviors. Thus, it is very necessary to discover how participants collaboratively build knowledge and jointly regulate themselves.

This book highlights the methodological approaches to analyzing knowledge building as well as the importance of socially shared regulation in collaborative learning. How do you objectively analyze knowledge building processes and outcomes in collaborative learning? What methods or techniques can be adopted to analyze and promote socially shared regulation? What modes of collaborative learning can be appropriately applied in elementary and higher education? These are precisely the questions that this book can help to answer.

It is an honor to have such a timely and comprehensive monograph written by Dr. Lanqin Zheng. Dr. Lanqin Zheng made great efforts in validating the new analysis method as well as exploring how to make use of collaborative learning through her own experiences. I believe that the topics of this book are useful not only for researchers but also for practitioners. For researchers, Chaps. 1–6 may be of interest because these demonstrate the new analysis method and new perspectives. For practitioners, Chaps. 7–10 may be of most interest since these provide practical guidelines and examples of CSCL practices. Hopefully the readers can benefit a lot from this book.

Prof. Ronghuai Huang

Preface

Collaborative learning has been widely adopted in the field of education. The advantages of collaborative learning have been well documented in the literature. This book centers on two crucial issues of collaborative learning. One is collaborative knowledge building, another is co-regulation and socially shared regulation. Successful collaborative learning depends on whether group members can co-construct knowledge as well as jointly regulate motivation, emotion, cognition, and behavior or not. This book aims to analyze collaborative knowledge building from the perspective of information flows and promotes co-regulation and socially shared regulation during collaborative learning. This book is structured into three parts.

Part I

The first part of this book consists of three chapters. This part focuses on analysis of collaborative knowledge building from the perspective of information flows. Chapter 1 proposes a new method to analyze the processes and outcomes of collaborative knowledge building. This method has been validated by 497 participants in both face-to-face and online collaborative learning. Chapter 2 aims to analyze knowledge elaboration based on a knowledge map approach. The indicator of measuring knowledge elaboration has been validated by 527 participants in face-to-face and online collaborative learning environments. Chapter 3 analyzes and validates the algorithm of knowledge convergence by 192 participants in an online collaborative learning environment.

Part II

The second part of this book consists of three chapters. This part focuses on analysis of co-regulation and socially shared regulation in collaborative learning. Self-regulated learning is not included in this part because regulation in a collaborative learning context mainly refers to co-regulation and socially shared regulation. Chapter 4 focuses on analysis of co-regulation behavioral patterns through a cluster and sequential analysis method in a CSCL environment. In addition to co-regulation, socially shared regulation is very crucial for successful and productive collaborative learning. Chapter 5 analyzes how group members collectively regulate themselves in a collaborative learning environment. Chapter 6 aims to promote collective efficacy, group cohesion, and collective regulatory skills through a socially shared regulation mechanism.

Part III

The third part of this book consists of four chapters. This part shares four case studies closely related to collaborative learning. In Chap. 7, the author shares how to promote productive collaborative learning through co-constructions of concept maps. In Chap. 8, the author seeks to revise the traditional jigsaw method to make collaborative learning more structured and productive. In Chap. 9, the author has developed peer assessment APP to facilitate real-time feedback and to engage students in collaborative learning. In Chap. 10, the author shares how collaborative inquiry learning is performed among four elementary schools over three months.

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I would like to express my gratitude to all those who provided support and help. Very special thanks go to Prof. Ronghuai Huang who directed me to the field of collaborative learning. He has provided support enabling me to conduct research on collaborative learning. I truly appreciate Prof. Kaicheng Yang who has guided me towards analyzing collaborative learning processes from the perspective of information flows. I would like to express my gratitude to Miao Zhang, Swetha Sethuraman, Tianran Chen, and their colleagues who have facilitated the publication of this book. Sincere thanks go to my master's students, Xin Li, Fengying Chen, Miao Liang, and Junhui Yu who helped me to collect and analyze data. There is much support to be grateful for coming from my family, my father, my husband, and my lovely son. My loving thanks to you!

I am very proud to present my first monograph that I have written in English. I am convinced that my efforts will contribute to grasping the value of collaborative learning and will improve the quality of learning for our children and for us.

Beijing, China Lanqin Zheng

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Contents

Part I
Analysis of Collaborative Knowledge Building

Chapter 1
A Novel Approach to Analyzing Collaborative Knowledge Building in Collaborative Learning

Abstract Collaborative learning has been widely used in the field of education. As a major activity, collaborative knowledge building has attracted growing interest in the field of collaborative learning. How to analyze collaborative knowledge building process and outcomes is the major concern in this field. Different approaches and analytical methods have been explored in order to analyze and evaluate collaborative knowledge building. This study proposes an innovative analytical method named the IIS (interactional information set)-map-based analysis method for analyzing collaborative knowledge building in collaborative learning. In total 497 undergraduate students consisting of 153 groups participated in this study. The results indicate that the IIS-map-based analysis method is an effective method to analyze collaborative knowledge building. The activation quantity of the final knowledge map can predict the level of collaborative knowledge building. The implications of this new method and future studies are also discussed.

Keywords Collaborative knowledge building · Collaborative learning · Information flows

1.1 Introduction

Collaborative learning has attracted much attention in the field of education in recent years. Collaborative learning "is a situation in which two or more people learn or attempt to learn something together" (Dillenbourg 1999). Numerous studies have revealed that collaborative learning can lead to critical thinking (Garrison et al. 2001), shared understanding (Roschelle and Teasley 1995), and good social relationships (Johnson and Johnson 1999). In order to produce effective collaborative learning, five basic elements have been proposed by Johnson and Johnson (1999), namely positive interdependence, face-to-face promoting interactions, individual accountability, interpersonal skills, and group processing. Among these five elements, face-to-face interaction can be transformed into synchronous interaction or asynchronous interaction if supported by computers or mobile devices.

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Previous studies have indicated that social interaction plays a very crucial role in collaborative learning (Kreijns et al. 2003; Stahl et al. 2006). Typically, there are two approaches to social interaction. The first is the socio-cognitive approach, which focuses on individual development in the social interaction context. The second is the socio-cultural approach, which focuses on the causal relationship between social interaction and individual cognitive change (Dillenbourg et al. 1996). The common trait of these two approaches is that individual cognitive development is based on social interaction. Moreover, the degree of interaction should be determined by the extent to which social interactions influence an individual's cognitive process (Dillenbourg 1999).

Generally speaking, building collective knowledge, making shared understanding, and creating significant artifacts are fundamental activities in collaborative learning (Stahl 2008). Group members can share information, build common understanding, make artifacts, construct knowledge, and create knowledge through social interaction during collaborative learning. Among these activities, collaborative knowledge building has gained more interest since Scardamalia and Bereiter (2003) proposed knowledge building to the field of education for the first time. The importance of collaborative knowledge building is widely recognized nowadays. Collaborative knowledge building in a collaborative learning context refers to how group members collaborate to construct knowledge and to learn in groups (Chan 2012). Collaborative knowledge building emphasizes collective and increasing responsibility for building a community's knowledge (Scardamalia and Bereiter 2006).

In order to examine how group members co-construct knowledge in collaborative learning, researchers have attempted to adopt various kinds of methods to analyze the process and outcomes of collaborative learning. The commonly used analytical methods include the conversation analysis method, the social network analysis method, and the content analysis method. The following section will illustrate each of these methods in detail.

1.2 Literature Review

Different analytical methods have been adopted to analyze the process and outcomes of collaborative knowledge building. In order to obtain evidence of collaborative knowledge building, various kinds of data sources have been collected to triangulate the research findings. For example, group products, logs, posts, questionnaires, interviews, journals, as well as pre- and post-tests are the major data sources. Furthermore, researchers often take some time to collect data, ranging from several days to several months, even several years. Since studies often differ from research purpose or research question, the central concerns are also different. For example, some studies focus on analysis of the contribution of group members, some studies focus on analysis of quality of posts. In this section, the commonly used analytical methods will be illustrated in detail.

The conversation analysis method is often employed to analyze the process of collaborative knowledge building. Conversation analysis centers on how speakers and hearers collaboratively produce sensible ideas by talk-in-interaction (Koschmann 2013). Conversation analysis provides a new way to get a better understanding of social interactions in collaborative learning (Koschmann 2011). Turn-taking, sequence construction, and repair organization are the three basic elements of conversation analysis (Schegloff 1992). The analysis of how group members take speaking turns, construct adjacency pairs and sequences, as well as organize repairs in social interactions can shed light on the nature and processes of collaborative knowledge building. In order to promote productive interactions and improve ideas in collaborative knowledge building, turn design, sequence construction, and repair organization are essential to provide insights into how intersubjective meaning occurs among group members. In addition, the transcripts of conversation analysis include what is said, intonation, volume, pace, and timing (Koschmann 2013). Previous studies have adopted the conversation analysis method to understand group discourse or classroom discourse during collaborative knowledge building. Caswell and Bielaczyc (2002) examined the knowledge-transforming discourse in knowledge forums to understand the evolution of scientific knowledge during an investigation of islands. Zhang and Sun (2011) analyzed idea improvement in a knowledge building community by analysis of online discourse supported by a knowledge forum.

The social network analysis method is another commonly used approach when analyzing the pattern of collaborative knowledge building. Social network analysis considers social relationships as nodes and ties. Nodes represent actors and ties represent the relationships among the actors (Wasserman and Faust 1994). The major indicators in the social network analysis method include betweenness, bridge, centrality, centralization, closeness, the clustering coefficient, cohesion, degree, density, and so on (Wasserman and Faust 1994). These indicators are often used to analyze the participation and contribution pattern of collaborative knowledge building. For example, Zhang et al. (2009) employed the social network analysis method to examine online participatory patterns and knowledge advances so as to provide insight into collective cognitive responsibility. Hong et al. (2010) analyzed different network structures for participants and idea interaction in the knowledge society network.

The content analysis method is the most often used method when analyzing collaborative knowledge building processes. The content analysis method is conceptualized as "the research method that builds on procedures to make valid inferences from text" (Rourke et al. 2001). Usually researchers adapt the existing coding schemes or develop a new coding scheme to analyze how group members build knowledge. Many coding schemes were developed and adopted in previous studies. For example, Zhu (1996) developed a coding scheme to analyze meaning negotiation and knowledge building for a distance-learning course. Gunawardena et al. (1997) examined the social construction of knowledge in computer conferencing via the content analysis method. Pena-Shaff and Nicholls (2004) developed a thematic category system to describe online interactions in order to analyze and evaluate knowledge building processes during online discussions. Weinberger and Fischer (2006) developed a multi-dimensional framework to analyze argumentative knowledge building in a CSCL environment. However, most of these coding schemes focus only on speech acts, such as questions, replies, discussions, elaborations, explanations, arguments, reflections, and so on. There are several disadvantages to code transcripts for speech acts. First, how learners construct knowledge is often ignored if you only center on speech acts. Second, the contextual evidence cannot be obtained because coding assigns speech acts an isolated meaning (Suthers et al. 2010). Third, it is very difficult to code discussion transcripts into speech acts because the purpose of such speech acts are implicit (Zheng et al. 2012), therefore, the coding results will be very subjective. Finally, reliability and validity are major concern for the content analysis method. Strijbos et al. (2006) believed that unit boundary overlap affected the reliability and validity of the content analysis method. Therefore, the replication of coding schemes will be limited to other research settings.

To sum up, the existing analysis methods have been employed to serve a different research purpose. However, analysis of the level of collaborative knowledge building from the perspective of knowledge and relationships remains lacking. The present study proposes an innovative analysis method that can analyze the process and outcomes of collaborative knowledge building in collaborative learning. The following section will describe this new method and the empirical study in detail.

1.3 The IIS-Map-Based Analysis Method

The proposed IIS-map-based analysis method is based on the information flow approach, which considers a collaborative learning system as an abstract information system. This innovative approach focuses on information flows within a collaborative learning system. The information flows are generated by group members during collaboration. The functionality of the collaborative learning system is to collaboratively build knowledge, skills, methods, emotions, attitudes, as well as values by group members. The present study aims to verify that the IIS-map-based analysis method can analyze the process and outcomes of knowledge building both in face-to-face and online collaborative learning.

The main theoretical foundation of this new approach is that knowledge building is closely related to information processing (Wang et al. 2011). Mayer (1996) believed that learners need to select relevant information, organize information, and integrate information with prior knowledge when they construct knowledge. Osborne and Wittrock (1983) also reported that integrating prior knowledge with new information can lead to making meaning and constructing knowledge. Therefore, we argue that the nature of knowledge building is to process information implicitly, including encoding and decoding information (Zheng et al. 2012). The information flow is the output and constructed by group members during collaboration. Thus, the interaction among group members involves sharing information flows, making meaning, and constructing knowledge. The information flow is visible, while knowledge is invisible and needs to be externalized. So information flows can be analyzed directly in order to provide insights into how learners co-construct knowledge during collaborative learning. The following section illustrates the three steps of IIS-map-based analysis method.

First, draw the initial knowledge map based on the collaborative learning objectives and tasks. The domain knowledge can be represented by the initial knowledge map, which can be drawn based on the selected norm. The nodes on the initial knowledge map denote knowledge and the edges denote mutual relationships of knowledge.

Second, code and segment information flows based on the following format:

$$
\begin{aligned}
&< \text{Time} > \; < \text{IPL}_i > \; < \text{Cognition level} > \; < \text{Information type} > \\
&< \text{Representation format} > \; < \text{Knowledge sub-map} >
\end{aligned}
$$

Here, time denotes the start time of the information flow; IPL_i denotes the information processing of different learners; the cognition level includes discerning, remembering, understanding, and applying; the information types include contexts, objectives, knowledge, facts and examples, management instructions, relevant information, and off-topic information; the representation format denotes text, graph, table, sound, video, animation, and body language; the knowledge sub-map denotes part of initial map. The information output flows of group members can be coded based on this format and mapped onto the knowledge sub-map. In addition, rules of segmenting information were developed based on analyzing the large number of samples. The rules specify that information flows will be segmented when the learner, or cognition level, or information type, or knowledge sub-map changes. However, if the representation format changes, information flows will not be segmented because each information flow can be represented by multiple formats.

Third, compute the attributes of information flows and generate the final knowledge map. We assume that some attributes of information flows can predict group performance. The following section will illustrate these attributes one by one. Traditionally, group performance is measured by pre-test and post-test. However, the process of knowledge building is ignored through pre-test and post-test. Therefore, the process-oriented method is called for so as to provide insights into how group members build knowledge together. The IIS-map-based analysis method puts emphasis on the process of collaboratively constructing knowledge. Furthermore, the level of collaborative knowledge building can be automatically calculated by this innovative method.

1.4 Research Hypotheses

The present study assumed that the following attributes of information flows can predict group performance.

H1: The activation quantity of the final knowledge map can predict the level of knowledge building.
H2: The average activation quantity of the final knowledge map can predict the level of knowledge building.
H3: The standard deviation of activation quantity of the final knowledge map can predict the level of knowledge building.

The activation quantity of the final knowledge map can be calculated by Eq. 1.1. We assume that the activation quantity of the final knowledge map can measure the level of co-construction of knowledge by group members.

$$A = \sum_{i=1}^{N} \sum \frac{F * \log(d + 2) * r}{\log(n * (D - d + 2))} \tag{1.1}$$

where d denotes the number of activated edges; D denotes the total number of edges; n denotes the categories of edges that are not activated; both F and r are adjustable parameters; and N denotes the number of knowledge in the final map. For more details see Zheng et al. (2012).

The average activation quantity of the final knowledge map can be calculated by Eq. 1.2.

$$\bar{A} = \frac{A}{N} \tag{1.2}$$

where A denotes the activation quantity of the final knowledge map and N denotes the number of the nodes in the final knowledge map.

The standard deviation of the activation quantity of the final knowledge map can be calculated by Eq. 1.3.

$$S = \sqrt{\frac{\sum_{i=1}^{N} \left(A_i - \overline{A}\right)^2}{N}} \tag{1.3}$$

1.5 The Empirical Study

The purpose of this empirical study is twofold: first, it aims to validate the IIS-map-based analysis method as a means of analyzing knowledge building. Second, it aims to examine whether the activation quantity of the final knowledge map can predict the level of collaborative knowledge building. The following section will illustrate the participants, collaborative learning tasks, experimental procedure, and data analysis method in detail.

1.5.1 Participants

The participants were recruited from one university in Beijing. They all majored in education, psychology, computer science, and educational technology. Some 497 undergraduate students volunteered to participate in this study—85 % of them were female. They were randomly divided into 153 groups of three or four participants. Among these 153 groups, 121 groups conducted face-to-face collaborative learning and 32 groups conducted online collaborative learning.

1.5.2 Samples

The samples from the study were from knowledge maps *not* the participants. Each group generated one knowledge map subsequent to collaboration. Therefore, 153 knowledge maps were generated in this study. Hence, it comprised 153 samples.

1.5.3 Collaborative Learning Tasks

The collaborative learning tasks covered five topics, including how to understand curriculum objectives, the application of consumer behavior theory in microeconomics, the application of knowledge transfer theory, the theory of graphs in data structure, and problem solving strategies. These five tasks included four kinds of knowledge, namely concepts, principles, processes, and facts as well as examples of comprehensive knowledge. For each collaborative learning task, the real-life learning context was provided to participants so as to stimulate interest in collaborative learning. The task assignment depended on participants' subject domain. Assignment of tasks was as follows: 30 groups completed a task regarding how to understand curriculum objectives; 30 groups completed a task about the application of consumer behavior theory; 31 groups completed a task about the application of knowledge transfer theory; and 30 groups completed a task about the theory of graphs in data structure. These 121 groups conducted face-to-face collaborative learning at different time slots. In addition, 32 groups completed a task about problem solving strategies. These 32 groups conducted online collaborative learning in different labs via instant message software. A research assistant was available only if groups needed help concerning experiment procedure. All of the participants only took part in the experiment once.

1.5.4 Experimental Procedure

The experimental procedure included the following steps.

First, researchers designed collaborative learning tasks based on the objectives of collaborative learning. The subject domain knowledge needed to be instructed in advance. The purpose of collaborative learning was to strengthen what the participants learned earlier as well as generate new ideas.

Second, the initial knowledge map was drawn based on the collaborative learning tasks. Five knowledge maps were drawn according to the five collaborative learning tasks in the study. The items of pre-test and post-test were also designed ahead of time based on the collaborative learning objectives and tasks. The test items of pre-test and post-test were identical.

Third, participants were recruited by advertising on distributed posters on campus. Before collaborative learning, all of the participants were randomly assigned one group of three or four. Then, they took the pre-test for about 15 min.

Fourth, participants conducted collaborative learning for about 2 h. The breakdown of groups was as follows: 30 groups focused on understanding curriculum objectives; 30 groups focused on the application of consumer behavior theory in microeconomics; 31 groups centered on the application of knowledge transfer theory; and 30 groups focused on the theory of graphs in data structure. The whole face-to-face collaborative learning process of each group was recorded by video. In addition, 32 groups conducted online collaborative learning by instant messaging software. The discussion transcripts were automatically recorded by the software. The post-test was taken immediately after collaborative learning so as to ensure the validity of the experiment. It took about one year to collect the data from the 153 groups.

Fifth, researchers coded and segmented all the data based on the above-mentioned format and rules. At least two raters coded and segmented data of one group in order to assure reliability of the study. It took about one year to code and segment the information flows from the 153 groups.

Finally, the activation quantity of the final knowledge map was calculated using software. Each group generated one knowledge map. The knowledge maps were therefore different in terms of knowledge and relationships for each of the different groups. Thus, 153 knowledge maps were generated after analyzing all of information flows. In the next section we illustrate how to analyze the data using our software.

1.5.5 Data Analysis

The present study adopted an innovative analysis method, namely the IIS-map-based analysis method to analyze the discussion transcripts of 153 groups. An analytical tool was developed by us to draw the initial knowledge map, code information flows, and compute the activation quantity of the knowledge map. Figure 1.1 shows the initial knowledge map drawn via our analytical tool. Table 1.1 shows the discussion transcripts of one group. Each sentence can be viewed as one information flow. All of information flows in Table 1.1 can be coded

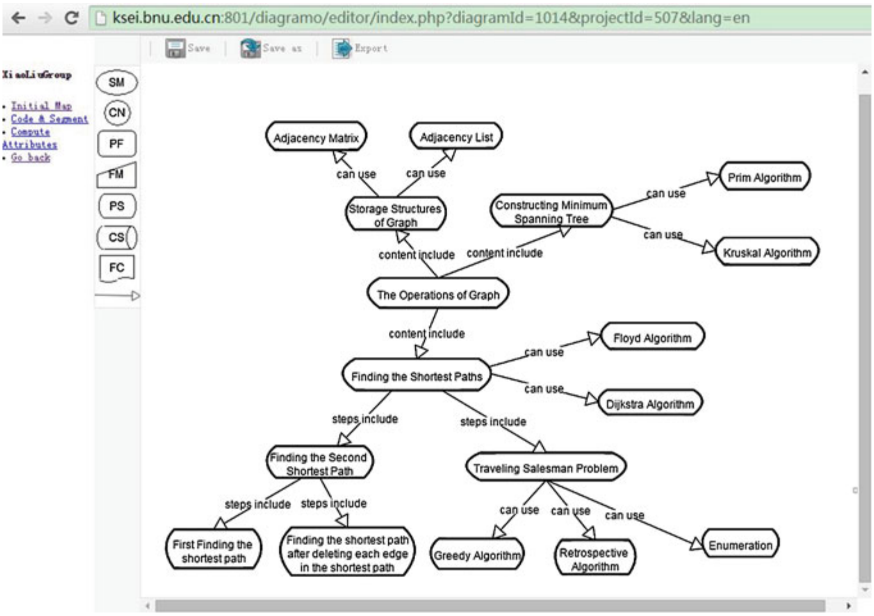

Fig. 1.1 The initial knowledge map

Table 1.1 Fragments of discussion transcripts

Time	IPL (Information Processing of Learners)$_i$	Discussion transcripts
44″	IPL_2	Do you think how to store the information about the title and introduction?
50″	IPL_1	I think maybe we should find the shortest paths
1′13″	IPL_3	Oh. No. Let's look at the task first
1′56″	IPL_4	OK
2′09″	IPL_2	I think the most difficult problem is to solve the travelling salesman problem
2′14″	IPL_2	Do you have any ideas about it? I think we can use enumeration to try it
2′18″	IPL_3	Oh. But the greedy algorithm is also a good solution

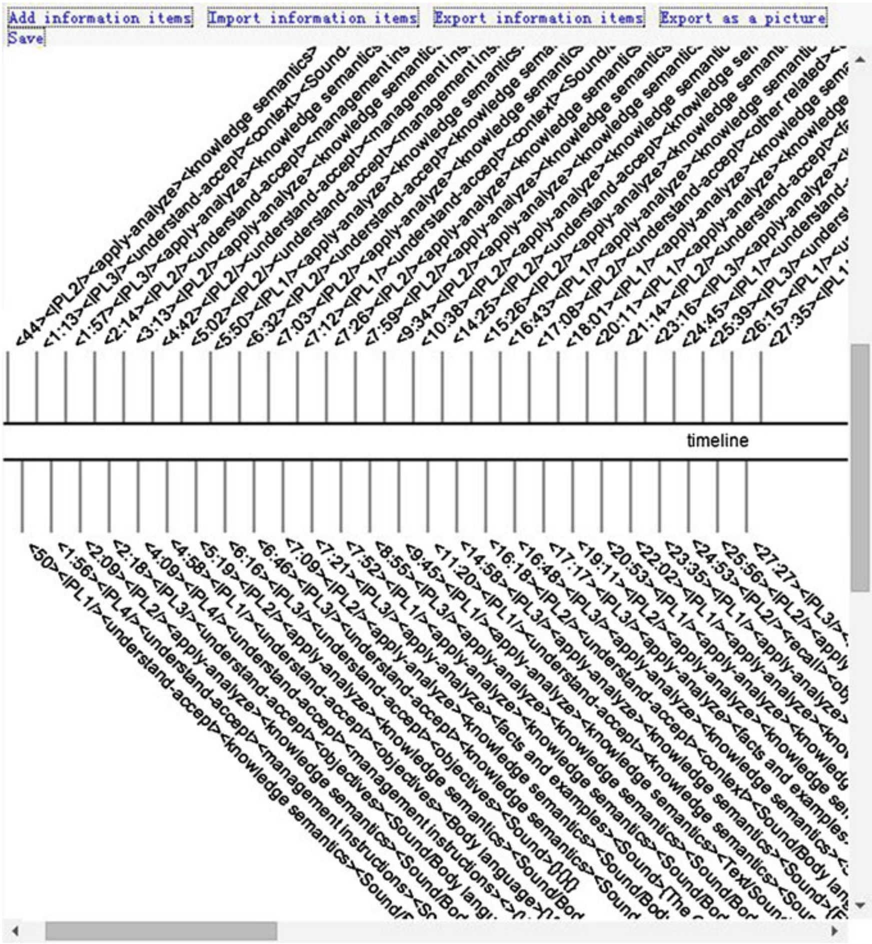

Fig. 1.2 The fragments of coding information flows

based on the aforementioned format and rules, as show in Fig. 1.2. Furthermore, Fig. 1.3 shows the final knowledge map with the activation quantity.

1.5.6 Inter-rater Reliability

Two trained coders independently coded the discussion transcripts of the 153 groups and assessed the test items of pre-test and post-test. The percentage agreement was used to calculate the inter-rater reliability. The results indicated that the reliability coefficients achieved values of 0.90 and 0.91 for coding discussion transcripts and assessing test items. All of the discrepancies were discussed face-to-face by two coders.

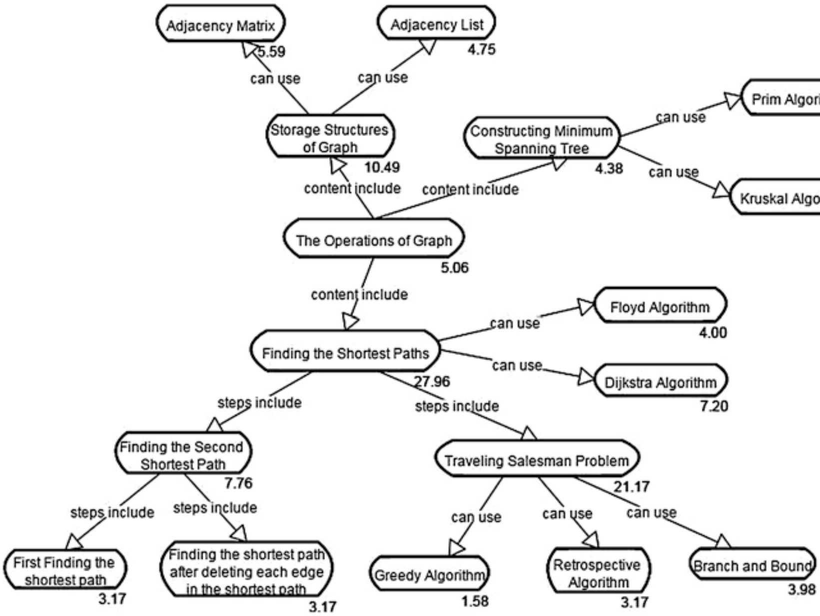

Fig. 1.3 The final knowledge map with the activation quantity

1.6 Results

1.6.1 Analysis of Knowledge Building in Face-to-Face Collaborative Learning Environment

Table 1.2 shows the descriptive statistical results for the group performance and the attributes of the information flows. Correlation analysis and linear regression analysis were conducted to test the hypotheses.

H1 assumed that the activation quantity of the final knowledge map can predict the level of knowledge building. The results indicated that the activation quantity of the final knowledge map was significantly positively related to group performance ($r = 0.487$, $p = 0.000$). Moreover, the results of the linear regression analysis indicated that the activation quantity of the final knowledge map can predict group performance (adjusted $R^2 = 0.230$, $\beta = 0.487$, $t = 6.077$, $p = 0.000$). The activation

Table 1.2 The descriptive statistical results of 121 groups

Items	Mean	Standard deviation
Group performance	24.45	14.61
The activation quantity	330.83	1.49
The average activation quantity	6.69	2.27
The standard deviation of activation quantity	7.14	3.64

quantity can explain 23 % of the total variance. These findings revealed that the activation quantity of the final knowledge map is the significant predictor for the level of knowledge building. Thus, H1 was supported.

H2 assumed that the average activation quantity of the final knowledge map can predict the level of knowledge building. The results indicated that the average activation quantity of the final knowledge map was positively associated with group performance ($r = 0.263$, $p = 0.004$). In addition, the results of the linear regression analysis indicated that the average activation quantity of the final knowledge map can also predict the group performance (adjusted $R^2 = 0.061$, $\beta = 0.263$, $t = 2.969$, $p = 0.004$). Therefore, the average activation quantity of the final knowledge map can only explain 6.1 % of the total variance. Thus, H2 was also supported.

H3 assumed that the standard deviation of the activation quantity of the final knowledge map can predict the level of knowledge building. The results indicated that the standard deviation of the activation quantity of the final knowledge map was not related to group performance ($r = 0.099$, $p = 0.280$). This means the standard deviation of the activation quantity of the final knowledge map cannot predict the level of knowledge building. Therefore, H3 was not supported.

1.6.2 Analysis of Knowledge Building in Online Learning Environment

Table 1.3 shows the results for the online collaborative learning environment. The findings indicated that the group performance was positively related to the activation quantity ($r = 0.369$, $p = 0.038$). However, the average activation quantity ($r = 0.305$, $p = 0.089$) and the standard deviation of the activation quantity were not related to group performance ($r = 0.265$, $p = 0.142$).

The findings of the linear regression analysis revealed that the activation quantity can predict group performance (adjusted $R^2 = 0.101$, $\beta = 0.361$, $t = 2.086$, $p = 0.04$). Therefore, the activation quantity can explain 10.1 % of the total variance. So H1 was supported in online collaborative learning environment. However, the average activation quantity and the standard deviation of the activation quantity cannot predict the level of knowledge building. Therefore, both H2 and H3 were not supported.

Table 1.3 The descriptive statistical results of 32 groups

Items	Mean	Standard deviation
Group performance	13.63	6.57
The activation quantity	620.44	275.04
The average activation quantity	10.57	3.84
The standard deviation of activation quantity	14.98	7.92

Based on the aforementioned results, the activation quantity of the final knowledge map was the best predictor for the level of knowledge building. Therefore, the activation quantity of the final knowledge map can be adopted to predict the level of knowledge building in the future.

1.7 Discussion

The findings of this study demonstrated that the activation quantity of the final knowledge map can significantly predict the level of knowledge building. In addition, the IIS-map-based analysis method can also analyze the knowledge building process in collaborative learning. The main reason for this was that the activation quantity of the final knowledge map represented the dynamic features of interaction as a whole, while the other two attributes cannot reflect the complex knowledge structures.

The study viewed collaborative learning as an information system. The information flows of the collaborative learning system were the central concern. The interaction information set was the sharing information set which helped learners to acquire domain knowledge. Jonassen (1999) believed that information was very necessary for learners to obtain knowledge and construct knowledge. Therefore, the present study focused on analysis of information flows during collaborative learning, which provided insights into how group members co-constructed knowledge. Thus, the level of knowledge building could be measured by the attributes of the information flows, namely the activation quantity of the final knowledge map.

The IIS-map-based analysis method is different from the previous approaches in several aspects. First, the sample was a knowledge map generated via output information from group members. The author believes that the knowledge was relatively objective and stable, while the learners varied regarding prior knowledge, personalities, and personal characteristics. Thus the research on the knowledge map can be replicated in other contexts. If we selected participants as the sample, it is very difficult to replicate the results in other educational contexts. Therefore, this innovative approach is more scientific than other approaches that focus on learners' characteristics. Second, the IIS-map-based analysis method focuses on the knowledge map. The nature of this method is to map information flows onto the knowledge map by natural language. The knowledge map serves as the reference when coding and segmenting information flows. The knowledge map consisted of different knowledge and their inter-relationships represent the level of collaborative knowledge building. Third, the IIS-map-based analysis method is more scientific and has a stronger predictive power for the level of knowledge building. The present study validated that the activation quantity of the knowledge map can predict the level of knowledge building. In contrast with previous studies that focused on speech acts during interactions, this new method focuses on the objective knowledge map and its features. Finally, the IIS-map-based analysis method demonstrates the temporal characteristics of interactions during collaborative learning. Previous studies also highlighted that temporal sequences played a vital role in collaborative learning (Stahl 2011).

However, the present study has several limitations. First, only the activation quantity of the knowledge map was validated to predict the level of knowledge building. A future study will explore other attributes of information flows that can strongly predict the level of knowledge building. Second, the sample size for online collaborative learning environment was very small. Follow up studies will examine this method by increasing sample sizes. Third, the present study only centered on analysis of knowledge building. How to analyze emotions, values, and attitude still need to be explored in future studies.

1.8 Conclusion

In conclusion, the present study revealed that the IIS-map-based method is an effective method that can analyze collaborative knowledge building in collaborative learning. This study also validated that the activation quantity of the knowledge map was an effective predictor for the 153 groups. The activation quantity of the final knowledge map can significantly predict the level of knowledge building.

There are many benefits to adopting the IIS-map-based analysis method. First, instead of the tests that only focus on results, this innovative analysis methodology is a process-oriented method that can analyze knowledge building processes. Second, knowledge building processes can be visualized by information sequences and knowledge maps. Third, the process and level of collaborative knowledge building can be analyzed and calculated by the IIS-map-based method. Fourth, mapping information flows output by group members onto a knowledge map can minimize the subjectivity of coding information into separate speech acts on a larger extent. Finally, the IIS-map-based analysis method can be replicable and applicable to various kinds of collaborative learning settings. Therefore, this study made a contribution to positioning this analysis method within the field of collaborative learning.

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Chapter 2
A Knowledge Map Approach to Analyzing Knowledge Elaboration in Collaborative Learning

Abstract This study aims to analyze and quantify the level of knowledge elaboration as well as examine the relationships between knowledge elaboration and group performance. A sample of 527 college students voluntarily participated in this study. They were randomly divided into 161 groups of 3 or 4 to conduct collaborative learning. In total, 121 groups conducted face-to-face collaborative learning and 40 groups conducted online collaborative learning. The collaborative learning task covered six topics. The results indicated that the knowledge map method can be used to analyze knowledge elaboration processes. The weighted path length of the activation spanning tree was a strong predictor of knowledge elaboration. The level of knowledge elaboration was significantly related to group performance. The practical implications of the findings are subsequently discussed.

Keywords Knowledge elaboration · Collaborative learning · Information flows

2.1 Introduction

It has been widely acknowledged that knowledge elaboration is an important activity for promoting knowledge gains during collaborative learning (Denessen et al. 2008; Golanics and Nussbaum 2008; Stegmann et al. 2012). Knowledge elaboration is conceptualized as organizing, interconnecting, restructuring, and incorporating new information with existing knowledge (Reigeluth et al. 1980; Weinstein and Mayer 1986). Previous studies have revealed that knowledge elaboration can facilitate the retention of the new information (Anderson 1983; Wittrock 1989), enhance meaningful learning (Novak 2002), and stimulate the integration of information into prior knowledge (Kalyuga 2009). Researchers have further indicated that knowledge elaboration had a significant effect on students' learning performance (Denessen et al. 2008; Hwang et al. 2007).

Furthermore, previous studies adopted different methods to analyze knowledge elaboration, including questionnaires (Draskovic et al. 2004), coding schemes (Eysink and de Jong 2012), think-aloud protocols (Stegmann et al. 2012), and

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assigning different values (Ding et al. 2011). However, these methods ignore the domain knowledge and cannot measure the level of knowledge elaboration. In addition, as yet, agreement on how to measure the level of knowledge elaboration has not been reached. Little research has been performed to determine how to quantify knowledge elaboration accurately and objectively. The present study aims to analyze and measure the level of knowledge elaboration beyond existing methods and scopes. The following research questions were investigated in the study:

- How to analyze knowledge elaboration in collaborative learning?
- How to measure the level of knowledge elaboration in collaborative learning?
- Can learners' knowledge elaboration level predict group performance?

2.2 Literature Review

Knowledge elaboration can be achieved better through collaborative learning, because when group members interact with each other during collaborative learning they process information and explain information to others. Thus, they frequently have to integrate prior knowledge with new information. Researchers also believed that interacting with others could promote information processing and the adjustment of cognitive structures (Mitnik et al. 2009; Wibeck et al. 2007), which could stimulate elaboration of knowledge to a large extent.

However, there is no consensus concerning the method of measurement of the level of knowledge elaboration. Typically, there are two approaches to coding knowledge elaboration. The first one is to develop schemes based on the research purposes and questions. For example, Van Boxtel et al. (2000) analyzed the characteristics of elaboration of conceptual knowledge through collaborative learning. They developed a code scheme to analyze elaborative episodes by categorizing utterance or episodes into giving elaborated answers, elaborated conflict, reasoning, and cognitive example elaboration. They also found that elaboration of conceptual knowledge was related to the individual learning outcomes in concept-mapping conditions. Stark et al. (2002) coded the behavior of example elaboration into cognitive example elaboration, meta-cognitive example elaboration, and other types of elaboration. The cognitive example elaboration dimension included principle-based considerations, goal-explication or goal–operator combinations, noticing coherence, and elaboration of situation. The meta-cognitive example elaboration dimension included positive monitoring and negative monitoring. Other elaboration meant that task texts or single solution steps were read off repeatedly. They found that the elaboration training had a positive effect on the quality of example elaboration. In addition, Denessen et al. (2008) constructed five verbal interaction categories to code cognitive elaborations, including instrumental help seeking, help giving with labeled explanations, challenging help received with labeled explanations, acknowledging help with labeled explanations, and self-questioning with labeled explanations. They found that students with a high ability showed more cognitive elaborations than students with low ability. Eysink and de Jong (2012) coded elaborative activities into developing and testing hypotheses, relating and integrating, and giving (self-) explanations. Their results suggested that elaboration was indeed the key learning process.

The second approach is to assign different values to represent elaboration during interactions. For example, van Ginkel and van Knippenberg (2008) assigned "1" when information was completely ignored by all four group members, assigned "2" when one of the members mentioned a crucial item of information but no one responded to it, assigned "3" when one of the members mentioned an item of information and at least one responded to it, assigned "4" when one crucial piece of information was mentioned and at least two or three members clearly reacted to them, assigned "5" when one crucial piece of information got fully discussed and at least two members responded to it, assigned "6" when at least two pieces of crucial information were fully discussed, and assigned "7" when all three crucial items of information were fully discussed. While Ding et al. (2011) assigned "−1" when the message was off task and distracted learners' attention, assigned "0" when the message was a task-related message but did not improve the problem solving, and assigned "1" when the message was related to the task and contributed to the final success of the problem solving.

In fact, the level of knowledge elaboration cannot be measured accurately by the previous approaches. There are many reasons for this. First, the current coding schemes only centered on speech acts of interactions. Thus, knowledge elaboration was ignored, which runs counter to the conception of knowledge elaboration. For example, the approach to coding discussion transcripts into developing hypotheses, relating and integrating, and giving explanations did not consider the processes of knowledge elaboration. Second, coding discussion transcripts into different speech acts is very subjective and can be ambiguous. The main reason for this is that the purpose of human behaviors is too implicit to judge accurately. Third, coding discussion transcripts into speech acts cannot record the process of knowledge elaboration.

To sum up, the previous approach can neither quantify the level of knowledge elaboration nor measure knowledge elaboration precisely. Therefore, the present study sought to adopt the graph theory approach to analyze and measure knowledge elaboration. Existing studies have reported that the graph theory is a promising and appropriate approach for analyzing knowledge structure (Ifenthaler 2010; Pirnay-Dummer et al. 2010). Moreover, Hwang et al. (2013) revealed that representing knowledge and relationships between knowledge via graphs is an effective way of evaluating learners' knowledge structure. Thus, this study adopted a knowledge map analytical approach to analyze and quantify the level of knowledge elaboration. The following section will illustrate the indicators, the analytical method, and the empirical study in depth.

2.3 Indicators of Knowledge Elaboration

In order to measure the level of knowledge elaboration, we assume that the following two graphical indices can serve as indicators of knowledge elaboration. The first indicator is the weighted path length of the activation spanning tree. The weighted path length of the activation spanning tree was adopted in Zheng et al. (2015). A spanning tree consists of all the vertices and some of the edges of a graph (Hassin and Tamir 1995). The activation spanning tree is created by activating knowledge in collaborative learning. The weighted path length of the activation spanning tree can be calculated by Eq. 2.1:

$$\mathrm{WPL} = \sum_{i=1}^{N} W_i L_i \tag{2.1}$$

where WPL denotes the weighted path length of the activation spanning tree; W_i denotes the weight of vertex i, which equals its activation quantity; L_i denotes the path length of vertex I; and N denotes the total number of vertices.

The second indicator is the degree distribution index, which indicates the relevance of knowledge and the connectivity of the knowledge map (Barabasi and Albert 1999). The degree distribution index can be calculated using Eq. 2.2:

$$D = e^{\frac{-2K \times \sum_{i=1}^{N} I_i \ln I_i}{N}} \tag{2.2}$$

where $D(G)$ denotes the degree distribution index and I_i indicates the importance of node i; $I_i = \frac{d_i}{\sum_{i=1}^{N} d_i}$ K denotes the total edges of the knowledge map; and N denotes the total number of vertices.

In addition, the group performance was measured by the average difference between the pre-test and post-test of group members.

The present study formulated the following two hypotheses:

H1: The weighted path length of the activation spanning tree can predict the level of knowledge elaboration.
H2: The degree distribution index can predict the level of knowledge elaboration.

2.4 Method

2.4.1 Participants

The present study recruited 527 college students by advertising at one university in Beijing. They majored in education science, psychology, economics, and computer science. Of the sample, 86 % of them were female. All of the participants were randomly divided into 161 groups of 3 or 4 people. All of them had experience of collaborative learning from previous courses. They could only participate in the experiment once.

2.4.2 Collaborative Learning Tasks

The collaborative learning tasks included six topics. These six topics cover different subject matter, including strategies for problem solving in general, self-regulated learning case studies, the conception and application of curriculum objectives, the theory of graphs, the application of consumer behavior theory, and the theory and application of knowledge transfer. Four of these were conducted in face-to-face collaborative learning settings with the other two being conducted in online collaborative learning settings. Among the 161 groups, 32 groups completed the task about strategies of problem solving in general via the online collaborative learning tool, 8 groups completed the task about self-regulated learning case study via the online collaborative learning tool, and 31 groups completed the task about the theory and application of knowledge transfer via face-to-face collaborative learning. The remaining 90 groups completed the remaining three tasks via face-to-face collaborative learning. For these three tasks, 30 groups completed one task face-to-face. A real-life context was provided to participants for each collaborative learning task. Here is an example of the self-regulated learning case study.

> Mike is a primary school student and he is not very interested in learning. However, he can finish the assignment on time. Sometimes he watches TV when he does his homework. His parents can find some errors when they check his assignments. He seldom read books in his spare time. Sometimes he does his homework until 11 p.m. or 12 p.m. before the new semester begins. He also does not know how to improve his learning strategies.

Please analyze this case and illustrate what is wrong with Mike's approach. Please also recommend appropriate self-regulated learning strategies for Mike. In addition, how do you help students to improve their self-regulated learning abilities if you are a teacher? Please discuss these questions with your group members online and formulate your ideas. The final product will be a written document expressing your opinions.

2.4.3 Experimental Procedure

This study adopted a pre-test/post-test research design. The experimental procedure was as follows.

First, the collaborative learning tasks and test items were designed based on collaborative learning objectives. In this study, six collaborative learning tasks were designed. Furthermore, the sample was a knowledge map. This was no different to the previous studies that viewed participants as the sample. In this study, each group generated one knowledge map. Therefore, different kinds of knowledge were selected to generate different knowledge maps. Concepts, principles, facts or examples, formats, and processes and steps were included in this study. Each collaborative learning task focused on one or two kinds of knowledge.

Second, participants were recruited using posters advertising the study on campus. Before collaborative learning, all participants received the same instructions about the purpose and procedures of the experiment. Then they took the pre-test lasting about 20 min. After that, they were randomly divided into different groups.

Third, participants collaborated face-to-face or online for approximately 2 h in different time slots. If they collaborated online, the each member was placed in different labs and was unable to discuss face-to-face. When students conducted face-to-face collaborative learning, researchers videotaped the whole collaborative learning process to be used as a data source. If they collaborated online, logs were automatically recorded by an instant message tool and used as data sources. For each collaborative learning task, there were about 30 groups participating in collaborative learning. The final product of each collaborative learning task was a written text. After they finished collaborative learning, the post-test was immediately administered to ensure no interference. The test items of pre-test and post-test were same so as to measure group performance.

2.4.4 Data Analysis

This study adopted the knowledge map analytical method to analyze the level of knowledge elaboration. There are three steps when analyzing and calculating the level of knowledge elaboration.

First, an initial knowledge map is drawn, based on collaborative learning tasks via the analytical tool. The initial knowledge map can be drawn based on domain knowledge related to a collaborative learning task. The initial knowledge map represents the mutual relationships of the domain knowledge. Figure 2.1 demonstrates a portion of an initial knowledge map, where SM represents symbols, CN represents concepts, PF represents principles, FM represents formats, PS represents processes and steps, CS represents cognitive strategies, and FC represents facts and cases (Zheng et al. 2015).

Second, code and segment information flows generated by group members. The coding format of information is as follows:

<Time> <IPLi><cognitive level><information type><representation format><knowledge sub-map>.

In this coding, time refers to the start time of the information flows and IPL_i denotes the information processing of different learners. The cognitive levels include discriminating or distinguishing, remembering, comprehending, and putting into practice. Information types include learning goals, learning environment,

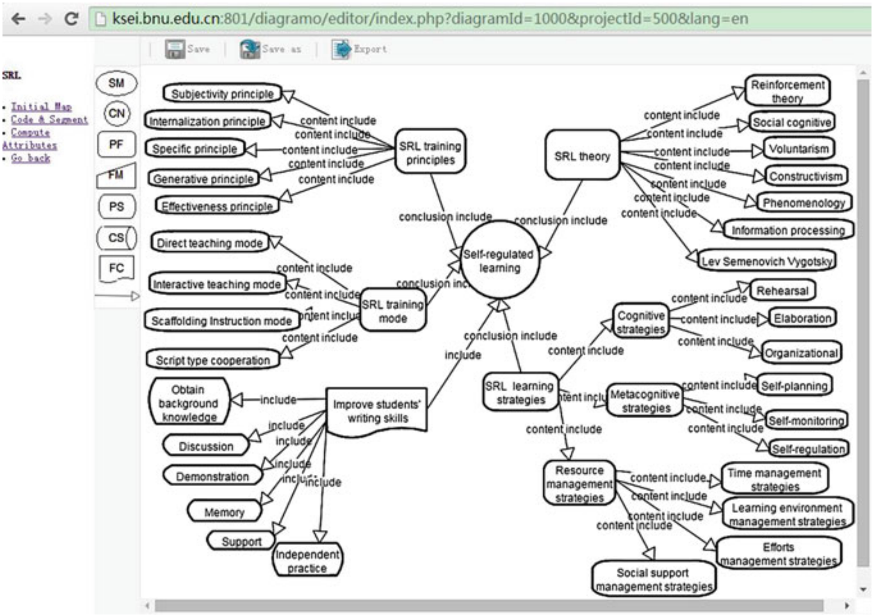

Fig. 2.1 A portion of the initial knowledge map

knowledge, questions, examples, management guidelines, and other information. The values of the representation formats include text, sound, graphs, photos, tables, videos, animations, objects, and body language. The knowledge sub-map, mapped by the output information flows, denotes pieces of knowledge and mutual relationships. Table 2.1 demonstrates the fragments of discussion transcripts from one group. In addition, Fig. 2.2 shows the fragments of coding and segmenting.

Table 2.1 Fragments of discussion transcripts

Time	IPL_i	Discussion transcripts
22″	IPL_2	Hello, do you remember whether we finished the similar task?
1′27″	IPL_1	No. This is the first time. There are lots of self-regulated learning theories
1′37″	IPL_3	The cases that I have learned are quite different from this one
1′56″	IPL_2	Oh. Really!
2′01″	IPL_1	Let's focus on this case
2′17″	IPL_2	I think there are many kinds of self-regulated learning strategies
3′08″	IPL_1	Yes, exactly. For example, resource management strategies, metacognitive strategies, and cognitive strategies
3′34″	IPL_2	Who can help to search for information?
4′06″	IPL_4	I can. I found meta-cognitive strategies include self-planning, self-monitoring, and self-regulation

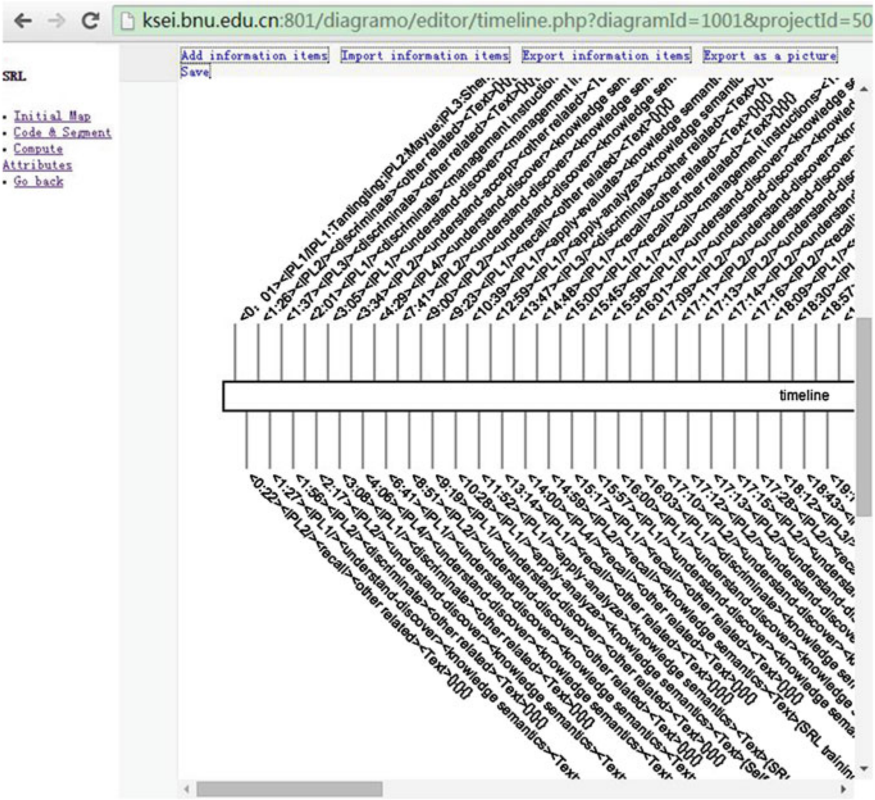

Fig. 2.2 Fragments of coding and segmenting

Third, the final knowledge map of each group was automatically generated. The level of knowledge elaboration was also automatically calculated by the analytical tool. Figure 2.3 shows the final knowledge map with weighted path lengths. The numbers next to the knowledge in Fig. 2.3 represent the weighted path lengths which can be calculated with Eq. 2.1 using the analytical tool.

2.4.5 Inter-rater Reliability

Two raters independently coded and segmented the information flows from the 161 groups via the abovementioned analytical tool. They also independently evaluated the 527 pre-test and post-test items. A percentage agreement index was adopted to compute the inter-rater reliability in this study. The reliability coefficient for coding information flows ranged from 0.87 to 0.92. All inter-rater reliability coefficients for

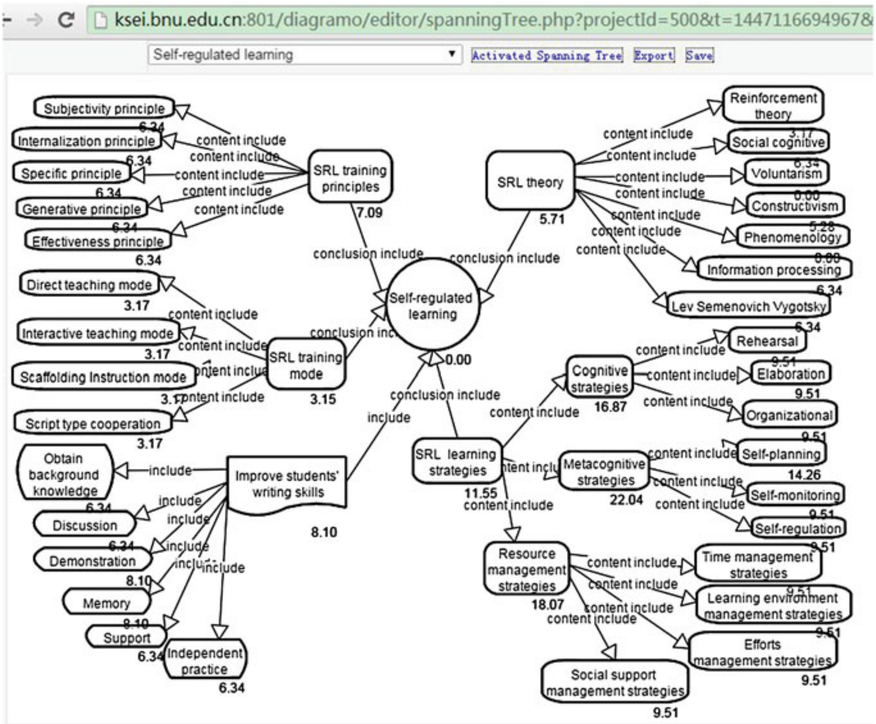

Fig. 2.3 Final knowledge map with weighted path lengths

assessing test items were above 0.9. The two raters discussed and resolved all discrepancies. These results indicated an excellent reliability for coding and assessing test items.

2.5 Results

In order to examine the two hypotheses in face-to-face collaborative learning and online collaborative learning, correlation analysis and regression analysis were conducted.

Table 2.2 shows the descriptive statistics for group performance, the degree distribution index, and the weighted path length of the activation spanning tree. In the face-to-face collaborative learning settings, the results indicated that the weighted path length of the activation spanning tree was significantly related to group performance ($r = 0.306$, $p = 0.001$). Furthermore, in order to examine the predictive validity of the weighted path length of the activation spanning tree on group performance, a linear regression analysis was conducted. The normal Q–Q

Table 2.2 Descriptive statistics in face-to-face collaborative learning settings

Items	Mean	Standard deviation
Group performance	24.45	14.61
The degree distribution index	6.303	0.844
The weighted path length of the activation spanning tree	844.63	447.69

plot was used to test normality of data. This test confirmed that the group performance variable had normal data. This is consistent with the hypothesis, in that the weighted path length of the activation spanning tree can predict group performance (adjusted R^2 = 0.086, β = 0.306, t = 3.503, p = 0.001). The weighted path length of the activation spanning tree can explain 8.6 % of the total variance. This indicated that the weighted path length of the activation spanning tree was the significant predictor. Therefore, H1 was supported in face-to-face collaborative learning settings. Moreover, the finding also revealed that the degree distribution index was positively related to group performance (r = 0.435, p = 0.000). In agreement with the hypothesis, the degree distribution index can also predict group performance (R^2 = 0.182, β = 0.435, t = 5.269, p = 0.000). The degree distribution index can explain 18.2 % of the total variance. These results indicated that the degree distribution index was another predictor in face-to-face collaborative learning. Thus, H2 was supported in face-to-face collaborative learning settings.

Table 2.3 shows the descriptive statistics for group performance n, the degree distribution index, and the weighted path length of the activation spanning tree in online collaborative learning settings. The findings indicated that the weighted path length of the activation spanning tree was significantly related to group performance (r = 0.356, p = 0.024). The results of linear regression analysis revealed that the weighted path length of the activation spanning tree can predict group performance (adjusted R^2 = 0.104, β = 0.356, t = 2.351, p = 0.024). The weighted path length of the activation spanning tree can explain 10.4 % of the total variance. Therefore, H1 was supported in online collaborative learning settings. However, the results also indicated that the degree distribution index was not related to group performance (r = 0.123, p = 0.448). Thus, the degree distribution index was not a significant predictor. Therefore, H2 was not supported in online collaborative learning settings.

Table 2.3 Descriptive statistics in online collaborative learning settings

Items	Mean	Standard deviation
Group performance	16.66	8.99
The degree distribution index	1734.35	795.53
The weighted path length of the activation spanning tree	1255.22	515.01

2.6 Discussion

To sum up, only the weighted path length of the activation spanning tree can be used to measure the level of knowledge elaboration both in face-to-face collaborative learning settings and online collaborative learning settings. The degree distribution index was not a significant predictor. The main reason for this is that the weighted path length of the activation spanning tree can measure the semantic richness of a knowledge map, namely the amount of semantic information contained in the knowledge map, while the degree distribution index only represents the topological characteristics of the knowledge map. Therefore, the weighted path length of the activation spanning tree can be adopted in future studies to measure the level of knowledge elaboration. Furthermore, the weighted path length of the activation spanning tree can be applicable for different types of knowledge, including concepts, principles, facts or examples, processes, as well as formats. In addition, consistent with previous studies (Noroozi et al. 2012; Stegmann et al. 2012), this study revealed that knowledge elaboration was positively associated with group performance. Furthermore, knowledge elaboration was found to significantly predict group performance in collaborative learning settings. Therefore, the weighted path length of the activation spanning tree can be adopted to measure the level of knowledge elaboration and predict group performance in future studies.

This study adopted the knowledge map analytical approach in order to analyze the process and level of knowledge elaboration. This innovative approach is based on graph theory, which focuses on the topology characteristics and semantic relationships of knowledge maps. The empirical results indicated that the semantic richness of the knowledge map was more important than the topology characteristics. The weighted path length of the activation spanning tree can better represent the richer semantic information than the degree distribution index. The knowledge map is considered as the sample in this new approach, because knowledge is relatively stable but learners are ever-changing. Therefore, this approach can be replicated in different contexts, representing a more scientific approach than previous studies.

This study has some implications for practitioners and educators. First, knowledge elaboration is helpful for meaningful and productive learning by integrating prior knowledge and new information (Kalyuga 2009). Therefore, the collaborative learning task should be designed to promote the link between prior knowledge and new information. Second, it is strongly recommended that prior knowledge related to the collaborative learning task should be reviewed before collaborative learning. Thus, learners find it easy to associate existing knowledge with new information. Third, examples, analogies, asking questions, and self-explanation can be adopted during collaborative learning in order to elaborate knowledge in depth. Fourth, summarizing what has been learned via drawing concept maps is very useful and effective for knowledge elaboration. Fifth, some useful tools such as the Cmap tool, Mindmanager, and iMindmap can be employed to organize ideas and concepts. Learners can also use these tools to collaboratively draw concept maps.

However, this study was constrained by several limitations. First, the weighted path length of the activation spanning tree only can explain 8.6 % of the total variance in face-to-face collaborative learning and 10.4 % in online collaborative learning, respectively. The prediction power is not very high. Therefore, the other indicators of knowledge elaboration need to be explored in future studies. Second, this study only examined how to measure the level of knowledge elaboration. How to promote knowledge elaboration needs to be investigated in future studies.

2.7 Conclusion

All in all, this study examined how to analyze and measure knowledge elaboration both in face-to-face collaborative learning and online collaborative learning. The findings indicated that knowledge elaboration processes and outcomes can be analyzed based on the knowledge map method. This innovative method views knowledge maps as the sample, which makes the study more scientific and replicable. The results also revealed that the weighted path length of the activation spanning tree can be adopted to calculate the level of knowledge elaboration both in face-to-face collaborative learning and online collaborative learning. Moreover, knowledge elaboration was significantly related to group performance. In the future, the level of knowledge elaboration can be employed to predict group performance without pre-test and post-test. In short, the main contribution of the present study lies in the indicator of knowledge elaboration and the knowledge map analytical method.

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Chapter 3
Analyzing Knowledge Convergence in CSCL: An Empirical Study

Abstract The assessment of collaborative learning is a central issue and its challenges are well known in this field. This study aims to analyze knowledge convergence through an innovative analytical method. A total of 192 participants were randomly divided into 48 groups of 4 people. They conducted online collaborative learning for 2 h. The process and outcome of knowledge convergence were analyzed by the knowledge map method in this study. The results indicated that the activation quantity of the common knowledge map is an effective indicator for knowledge convergence. Knowledge convergence can also significantly predict group performance in a CSCL context. The implications of the results and future studies are discussed in detail.

Keywords Knowledge convergence · Knowledge map · CSCL

3.1 Introduction

Collaborative learning is a coordinated and synchronous activity that aims to construct and maintain a shared conception of a problem (Roschelle and Teasley 1995). In order to obtain a shared understanding of subject matter, group members should have the same range of actions, the same level of knowledge, and a similar status concerning their community (Dillenbourg 1999). However, collaborators cannot achieve shared understanding without a certain degree of convergence. Researchers have indicated that convergence is more significant in explaining why collaborative learning leads to productive outcomes (Fischer and Mandl 2005; Roschelle 1996).

Convergence, especially knowledge convergence has attracted much attention in recent years (Kapur et al. 2011; Spemann and Fischer 2011). Convergence is an emergent behavior originating from the transactional interaction in collaborative learning (Kapur et al. 2011). Knowledge convergence is also viewed as evidence that collaborative learning has occurred (Roschelle 1996). Different researchers hold different opinions on knowledge convergence. However, it is widely

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acknowledged that knowledge convergence emphasizes increasing similarity with respect to knowledge among group members (Ickes and Gonzalez 1996; Jeong and Chi 2007; Weinberger et al. 2007).

Furthermore, it has been found that learners who converge in knowledge benefit more than learners who do not (Fischer and Mandl 2005). Collaborative learning has been considered as a mutual influence process through interactions among group members (Strijbos and Fischer 2007). However, how to assess the degree of mutual influence has not achieved a consensus. Researchers have also indicated that it is a big challenge to understand how to achieve convergence in collaborative learning (Fischer and Mandl 2005; Kapur et al. 2011). This study sought to understand and analyze the degree of mutual influence through the lens of knowledge convergence. The research questions addressed are as follows:

1. How to analyze knowledge convergence in collaborative learning?
2. How to measure the level of knowledge convergence in collaborative learning?
3. Can the level of knowledge convergence predict group performance?

3.2 Literature Review

3.2.1 Related Work

Knowledge convergence has been defined and operationalized in different ways. Roschelle (1996) believed that convergence refers to a mutual influence among collaborators. For example, part of a group has an impact on others, which in turn has an impact on their own learning activities. Ickes and Gonzalez (1996) considered knowledge convergence as the more uniform of cognitive responses among group members. Jeong and Chi (2007) defined knowledge convergence as an increase in common knowledge. Weinberger et al. (2007) operationalized knowledge convergence as knowledge equivalence and shared knowledge. Knowledge equivalence means that group members become more similar with regard to their knowledge. Shared knowledge refers to the concepts that all group members possess. Kapur et al. (2011) viewed knowledge convergence as an emergent behavior mediated by tools and artifacts from the perspective of complex systems. Therefore, convergent is a group-level phenomenon that cannot be attributed to an individual behavior.

Understanding the nature and mechanism of knowledge convergence is still a big challenge (Fischer and Mandl 2005). A sufficient level of convergence is only required to conduct a conversation on the same objects (Brennan and Clark 1996). However, a deep level of convergence means that collaborators form shared intentions and understandings of objects (Clark and Lucy 1975). So far, there has been considerable research examining how convergence occurs (Clark and Brennan 1991; Fischer and Mandl 2005; Kapur et al. 2011; Roschelle and Teasley 1995). As

Kapur et al. (2011) reported, convergence is an emergent behavior, which means that the simplicity of the individual-level can lead to the complexity of the collective-level (Bar-Yam 2003). Collaborative learning mainly occurs at the group level, thus, convergence can serve as a vehicle for unpacking how shared understanding is achieved.

Previous studies have adopted different approaches to measure the level of knowledge convergence. One approach is to adopt qualitative analytical methods to analyze convergence in collaborative learning. For example, the interaction analysis method, discourse analysis method, and conversation analysis method have all been adopted to examine the knowledge convergence processes (Barron 2003; Stahl 2005). These methods provide insightful accounts of knowledge convergence in collaborative learning. Another approach is to employ quantitative analytical methods to measure knowledge convergence. For example, Fischer and Mandl (2005) employed Euclidean distances of resource usage frequencies to measure knowledge convergence. Jeong and Chi (2007) argued that knowledge convergence refers to the increase in common knowledge. In their study they measured the level of knowledge convergence by subtracting the amount of common knowledge at the pre-test from the amount of common knowledge at the post-test. Weinberger et al. (2007) measured knowledge convergence through knowledge equivalence and shared knowledge prior to, during, and after collaborative learning. Knowledge equivalence is equal to the coefficient of variation of individual test scores. Shared knowledge can be calculated using the score of pair-wise comparisons of knowledge tests divided by the mean value of the group. Kapur et al. (2008) adopted content analysis to code discussion transcripts, and then they assigned different values to each interaction unit. A value 1 was assigned when the group discussion moved toward the goal of the activity. A value 0 was assigned when the group discussion maintained status quo. A value 1 was assigned when the group discussion moved away from the goal of the activity. The level of knowledge convergence can be calculated using the Eq. 3.1:

$$C = \frac{n_1 - n_{-1}}{n_1 + n_{-1}} \tag{3.1}$$

Additionally, Clariana et al. (2011) adopted the degree centrality of a graph to measure knowledge convergence. The degree centrality of a graph can be computed by Eq. 3.2:

$$C(G) = \frac{\sum_{i=1}^{v} [C(v^*) - C(v_i)]}{\max \sum_{i=1}^{v} [C(v^*) - C(v_i)]} \tag{3.2}$$

where $C(v_i)$ represents the degree centrality of the node v_i and $C(v^*)$ represents the highest degree of centrality.

To sum up, previous measures either depended on qualitative analysis of the interaction process, or on pre-test and post-test. However, convergence is a group-level phenomenon, which cannot be measured by individual behaviors. How to quantify the level of knowledge convergence objectively in collaborative learning still requires resolution.

3.2.2 The Present Study

This study aims to develop a more precise measurement of knowledge convergence in CSCL. In this study, knowledge convergence is defined as how much common knowledge was activated during and after collaborative learning. An innovative knowledge map analytical method was adopted to analyze the process and outcome of knowledge convergence. The following section illustrates this method and shows how to measure the level of knowledge convergence in detail.

3.3 Method

3.3.1 Participants

In total, 192 college students voluntarily participated in this study. They majored in educational technology, psychology, and educational science. Of these students, 85 % of them were female. The average age of the participants was 21 years old. All of the participants were randomly divided into 48 groups of 4 people. They had received experience of collaborative learning during previous courses. However, they never interacted with each other prior to this study. All of the students participated this study only once.

3.3.2 Collaborative Learning Tasks

The collaborative learning task was related to general problem-solving strategies. Participants needed to collaboratively illustrate strategies for solving ill-structured problems and identify differences between experts and novices. Of these groups, 48 completed the same collaborative learning task online. The final product was a written document about group members' solutions.

3.3.3 Procedure

The procedure comprised three phases, namely pre-test, collaborative learning, and post-test. In the first phase, the pre-test was administered to all participants. This pre-test took about 20 min to complete. Subsequently, 48 groups conducted collaborative learning online via Microsoft Service Network (MSN) in different labs in different time slots. It took about 2 h for each group to conduct collaborative learning. During collaborative learning, participants received no intervention except when they had procedural or technological problems. No specific training was performed for participants since they had prior experience of using MSN. In the last phase, the post-test was immediately administered to all participants after collaborative learning. The post-test took 20 min to complete. The items of pre-test and post-test were the same, i.e., open-ended questions about domain knowledge.

3.3.4 Measures

In this study, knowledge convergence was measured by the activation quantity of the common knowledge map, which is equal to the sum of the activation quantity of each vertex in the common knowledge map. This algorithm was developed in a previous study (Zheng 2015). The level of knowledge convergence can be calculated using Eq. 3.3:

$$C(G_1 \cap G_2 \cap G_3 \cap G_4) = \sum_{i=1}^{N} A_i = \sum_{i=1}^{N} \sum \frac{F * \log(d+2) * r}{\log(n * (D - d + 2))} \tag{3.3}$$

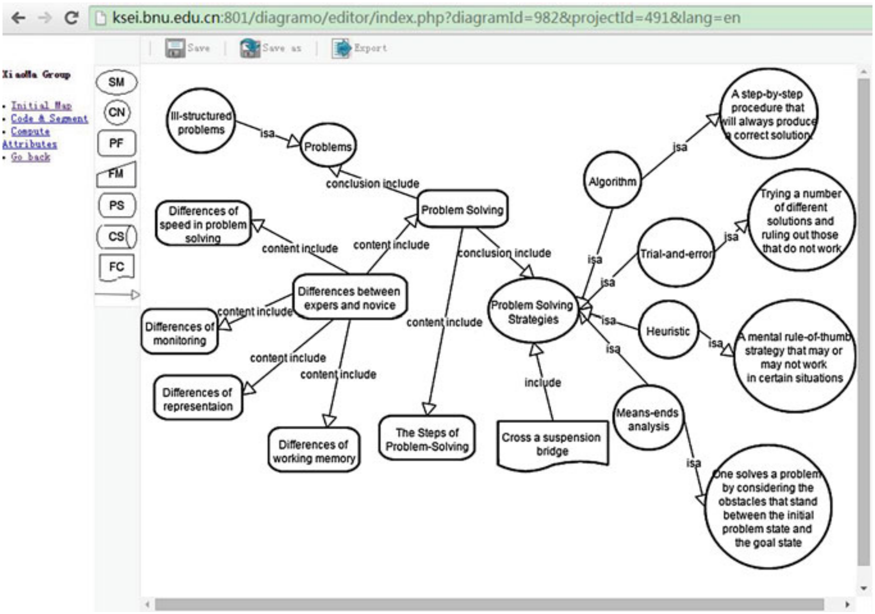

Fig. 3.1 A portion of the initial knowledge map

where $C(G_1 \cap G_2 \cap G_3 \cap G_4)$ denotes the level of knowledge convergence; $(G_1 \cap G_2 \cap G_3 \cap G_4)$ denotes the common knowledge map; G_1, G_2, G_3, and G_4 denote the knowledge map generated by each group member; A_i denotes the activation quantity of the common knowledge map, which is equal to $\sum \frac{F*\log(d+2)*r}{\log(n*(D-d+2))}$; and N represents the total number of vertices.

3.3.5 Data Analysis

This study adopted an innovative knowledge map analytical method and tools to analyze and compute the level of knowledge convergence. This new method is

Table 3.1 Fragments of discussion transcripts

Time	IPL_i	Discussion transcripts
6″	IPL_1	Hello, everyone. Let's get started
15″	IPL_2	This task is about the problem-solving strategies
20″	IPL_1	Yes, it is. It is related to the problem-solving strategies of crossing a suspension bridge
1′02″	IPL_3	Do you know any strategies of problem solving?
1′32″	IPL_1	Yes. For example, algorithm, heuristic, trial-and-error, and means-ends analysis method are strategies of problem solving
1′40″	IPL_2	Sure. I agree with you. Then what is the algorithm?
1′51″	IPL_1	An algorithm is a step-by-step procedure that will always produce a correct solution
2′10″	IPL_3	Oh. I see. I believe the algorithm is a very effective problem-solving strategy
2′15″	IPL_4	How about the heuristic?
2′20″	IPL_2	A heuristic is a mental rule-of-thumb strategy that may or may not work in certain situations
2′48″	IPL_1	You are right. I adopted the heuristic to solve the problem before. In addition, I have also used the means-ends analysis and trial-and-error before
3′19″	IPL_3	Oh. Yes. The trial-and-error refers to trying a number of different solutions and ruling out those that do not work. Then would you like to illustrate the means-ends analysis in detail?
3′53″	IPL_1	The means-ends analysis means that one solves a problem by considering the obstacles that stand between the initial problem state and the goal state
4′17″	IPL_2	But we should know that problems include ill-structured problems
4′25″	IPL_3	Sure. You know there are many differences between experts and novices in problem solving
5′01″	IPL_4	Really? Can you explain these differences?
5′16″	IPL_3	For example, experts and novices differ in representations of problems, speed of problem solving, working memory capacity, and how to monitor problem-solving processes
6′01″	IPL_4	Oh. Great. Let's talk about the steps of problem solving

comprised of three steps. First, it is required to draw the initial knowledge map based on the collaborative learning objectives and tasks. The initial knowledge map consists of nodes and edges, which represent knowledge and their mutual relationships, respectively. Figure 3.1 demonstrates the portions of the initial knowledge map.

Second, it is necessary to code information flows generated during collaboration, based on the rules of segmentation. These information flows can be automatically recorded by MSN. Each information flow can be coded into the following format:

<Time><IPL$_i$><Cognitive Level><Information type><Representation format><Knowledge sub-map>.

Table 3.1 shows fragments of information flows from one group, which can be coded and segmented into information sequences, as is shown in Fig. 3.2.

Third, calculate the activation quantity of the common knowledge map via the analytical tool. Thus, the activation quantity of each knowledge map can be calculated automatically using this tool. Figure 3.3 shows the final knowledge map with the activation quantity. This knowledge map is generated after collaboration. We can use the analytical tool to export the knowledge map generated by each group member. Then the common knowledge map can be formed correspondingly. Thus, the level of knowledge convergence can be computed using the Eq. 3.3.

The knowledge maps generated by each group member are shown in Figs. 3.4, 3.5, 3.6, and 3.7. The common knowledge map is shown in Fig. 3.8.

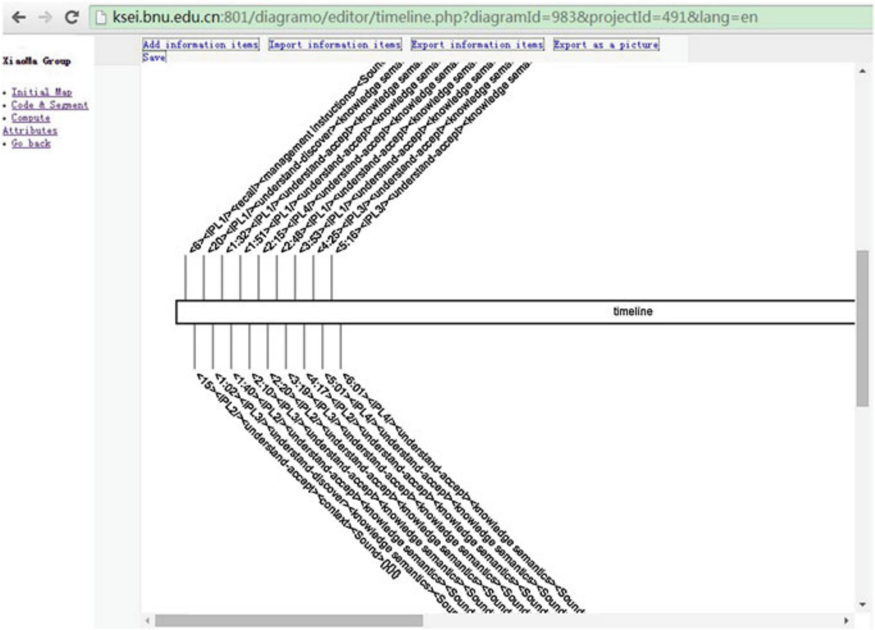

Fig. 3.2 Fragments of coding and segmenting

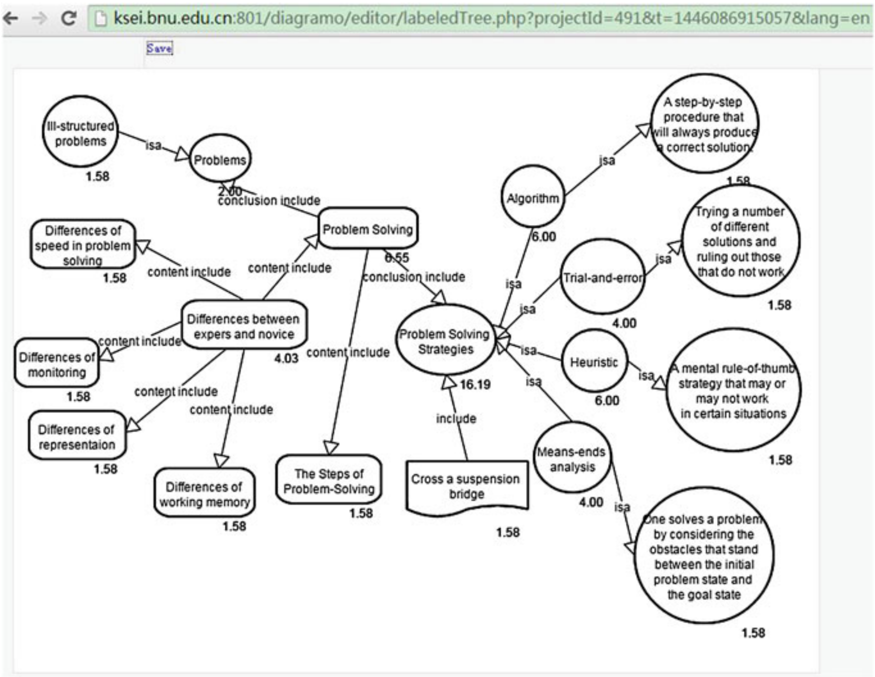

Fig. 3.3 Final knowledge map with the activation quantity

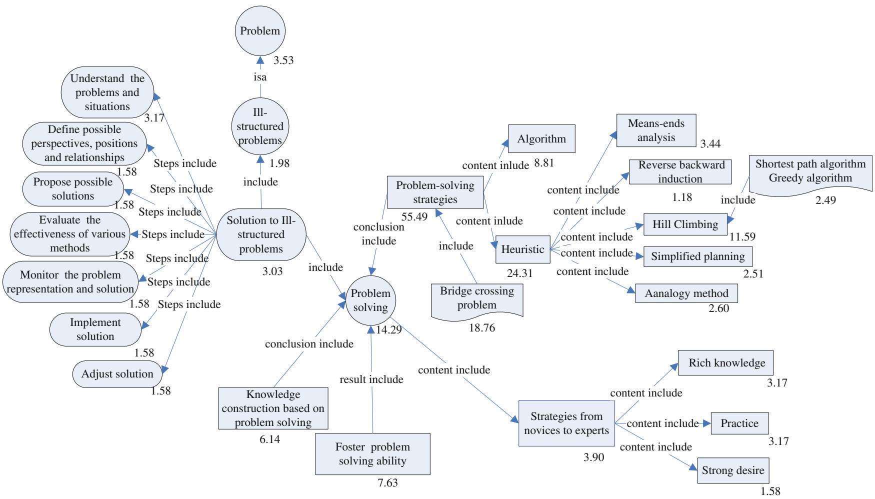

Fig. 3.4 The knowledge map generated by IPL_1

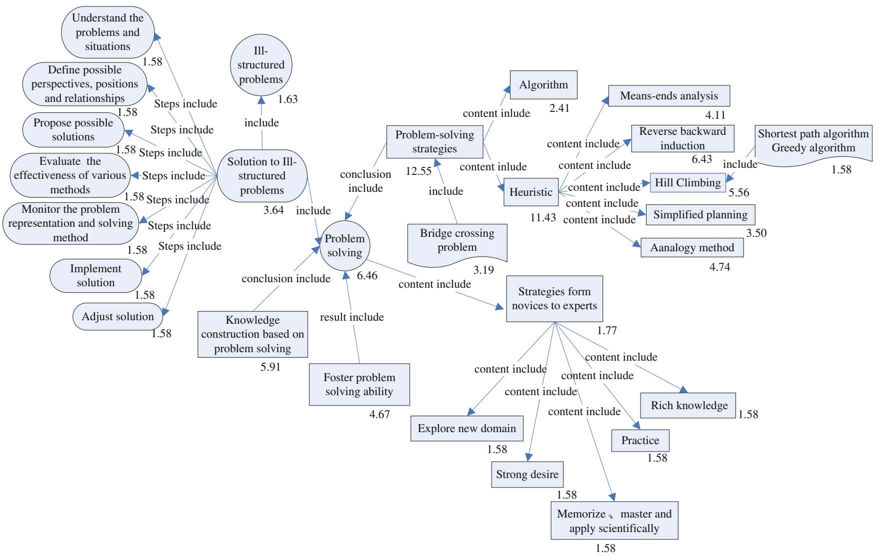

Fig. 3.5 The knowledge map generated by IPL_2

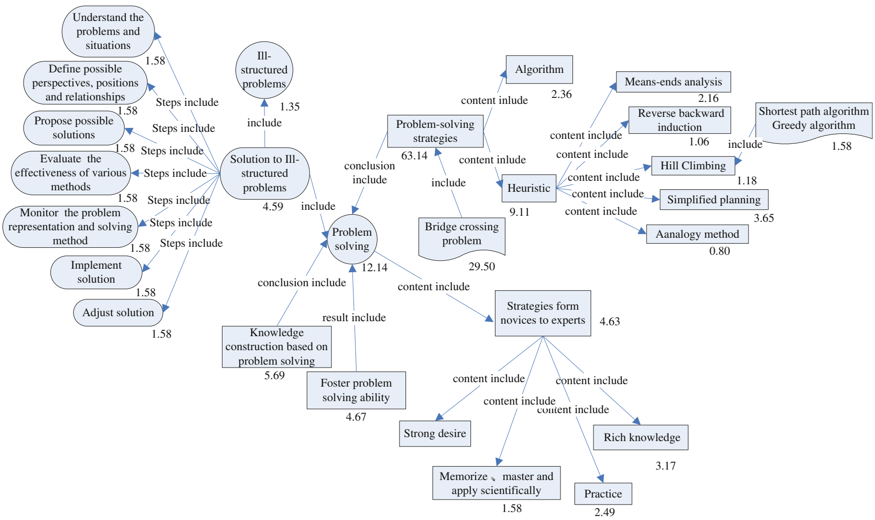

Fig. 3.6 The knowledge map generated by IPL_3

3.3.6 *Inter-rater Reliability*

Two trained raters independently coded and segmented all of information flows from the 48 groups. They also assessed the items of the pre-test and post-test. The

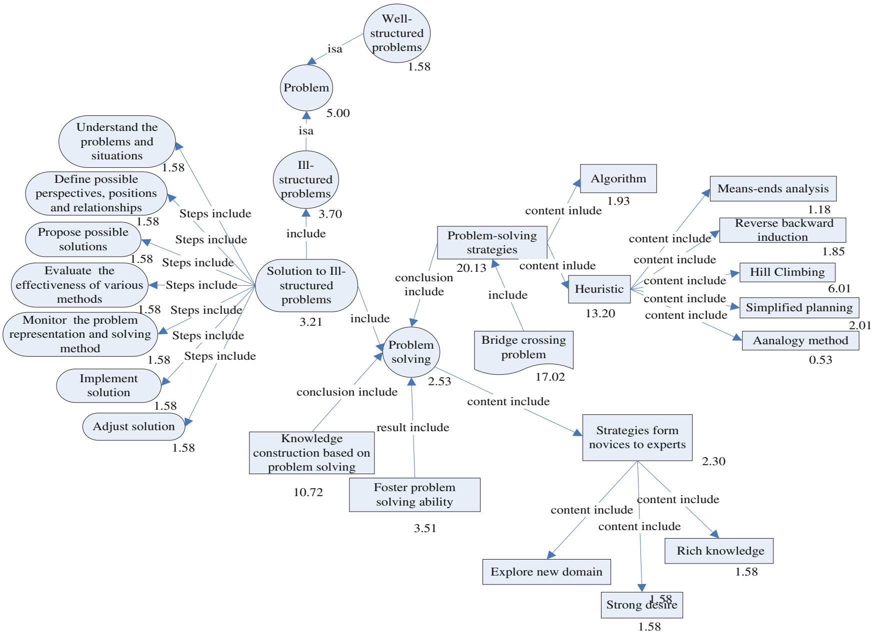

Fig. 3.7 The knowledge map generated by IPL_4

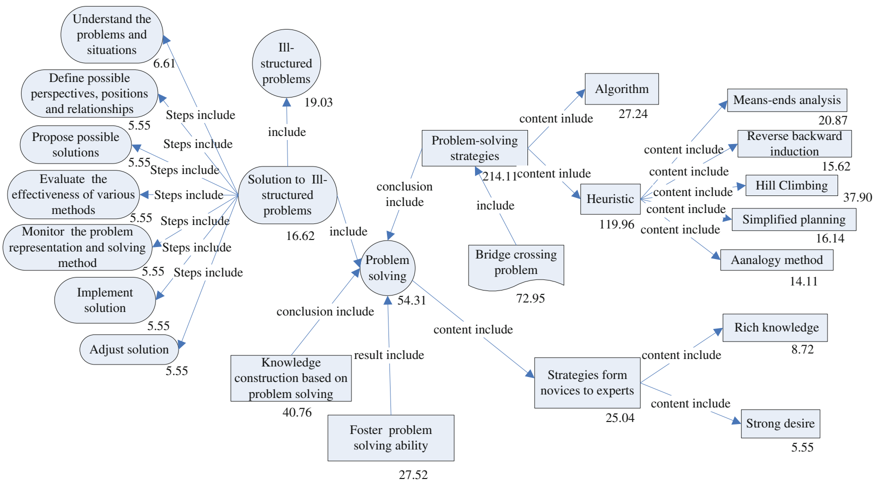

Fig. 3.8 The common knowledge map

percentage agreement achieved 0.83 for coding information flows and 0.85 for assessing the pre-test and post-test, respectively. All of the discrepancies were solved by face-to-face discussion.

3.4 Results and Discussion

In order to examine whether level of knowledge convergence can predict group performance, correlation analysis and regression analysis were conducted using SPSS 20.0 software. Table 3.2 shows the descriptive statistics for group performance and the level of knowledge convergence. The results indicated that the level of knowledge convergence was positively related to group performance ($r = 0.338$, $p = 0.019$). Moreover, linear regression analysis was conducted in order to examine the predictive validity of the level of knowledge convergence. The normal Q–Q plot was used to test normality of data. This test confirmed that the group performance variable had normal data. The findings revealed that level of knowledge convergence can predict group performance (adjusted $R^2 = 0.10$, $\beta = 0.338$, $t = 2.432$, $p = 0.019$). The level of knowledge convergence was found to explain 10 % of the total variance. The means that the level of knowledge convergence was a significant predictor. Therefore, the activation quantity of the common knowledge map can be adopted to measure the level of knowledge convergence.

This study adopted the innovative knowledge map method to analyze the process and level of knowledge convergence. The indicator of knowledge convergence was also developed and validated by the empirical study. The results indicated that level of knowledge convergence can be measured by the activation quantity of the common knowledge map. In addition, the level of knowledge convergence can significantly predict group performance. This result was in agreemen with Kapur et al. (2008) who found that the level of knowledge convergence was positively related to group performance. This finding was also confirmed in Cannon-Bowers and Salas' (2001) report that knowledge convergence was a strong indicator for group performance. Fischer and Mandl (2005) also found that learners who converged more in knowledge benefited more that those who did not. Our findings also yielded a similar result.

Convergence is the united arrival at a shared understanding of a problem or solution during collaboration (Hübscher-Younger and Narayanan 2003). Convergence is regarded as a positive phenomenon and proof that collaborative learning occurs (Fischer and Mandl 2005; Hübscher-Younger and Narayanan 2003; Roschelle 1996). Convergence on correct understanding and explanations is one of the goals of collaborative learning (Hübscher-Younger and Narayanan 2003). Furthermore, knowledge convergence is one important aspect of convergence, which focuses on knowledge building among group members. I also take the position that knowledge convergence can be achieved as a consequence of social

Table 3.2 Descriptive statistics of group performance and the level of knowledge convergence

Items	Mean	Standard deviation
Group performance	13.41	6.67
The level of knowledge convergence	122.77	115.02

interactions during collaboration. Moreover, mutual influence and reciprocity during collaborative learning can also lead to knowledge convergence.

However, it is so difficult to reach convergence in knowledge at the beginning of collaborative learning. Usually, group members have divergent ideas at first because they have different backgrounds and different levels of prior knowledge. Subsequently, they maybe become convergent because of social interaction. Sometimes they become more divergent after a long and heated discussion. This means that divergence comes in advance of convergence. However, this kind of divergence is perhaps helpful because sometimes convergence can be achieved only after divergence. Previous research also reported that divergence had a positive influence on convergence (Hoadley and Enyedy 1999; Jorczak 2011; Stahl 2002). This is because convergence can be achieved only if the conflicts or misconceptions appearing in the process of divergence are jointly solved. Generally speaking, moving from divergence to convergence is very common in collaborative learning.

In order to reach knowledge convergence, external support is necessary in collaborative learning since knowledge convergence cannot occur automatically. These support mechanisms include external representation tools, shared environments, and teacher facilitation. Earlier studies indicated that collaboration scripts were effective tools for support and promotion of knowledge convergence (Fischer and Mandl 2005). In addition, previous studies also indicated that group knowledge awareness tools can promote knowledge convergence (Dehler et al. 2009). Therefore, specific tools to support shared input are necessary. It is essential to be aware of group members' status in order to reach knowledge convergence. Of course, teachers can guide group members to be more convergent through different kinds of intervention. For example, teachers can remind group members when they are off-topic or deviating from the target.

This study adopted the innovative knowledge map approach to analyze the processes and outcomes of knowledge convergence. The level of knowledge convergence can be calculated by the activation quantity of the common knowledge map after collaboration. Thus, the outcome of knowledge convergence can also be visualized and represented through this knowledge map analytical method. This method provides insights into how group members become convergent in knowledge after collaboration. The common knowledge map can be generated using the analytical tool at any time. Thus, how knowledge convergence evolves over time can be clearly demonstrated through this method.

This study has several implications for teachers and practitioners. First, convergence should be encouraged because it is evidence of collaborative learning. Knowledge convergence indicates that knowledge building by group members has achieved a higher level. Second, some external representation tools should be provided for collaborators so they can achieve knowledge convergence in the shared collaborative learning environment. Third, divergence is permitted since divergence to some extent can lead to convergence. Knowledge convergence is a spiral and evolutionary process. Fourth, teachers should intervene at the appropriate time when they find collaborators are struggling to become convergent in knowledge. Finally, negotiation of conflicts, multiple cycles of explanations and clarifications, and a warm collaborative learning atmosphere help students reach a higher level of convergence.

This study was constrained by several limitations. First, the predictability of the indicator is not very high and still needs to be improved in future studies. Currently, the activation quantity of the common knowledge map only explained 11 % of the total variance. Second, all of the participants completed only one collaborative learning task. Future studies will examine the predictability of the indicator through multiple kinds of tasks. Remember that the sample of this study is the knowledge map. Usually, different tasks contain different kinds of knowledge. Therefore, other kinds of collaborative learning tasks need to be designed in future studies. Third, sample size needs to be enlarged in future studies. It would also be very interesting to explore whether the findings of this study are applicable to other contexts.

3.5 Conclusion

This study adopted an innovative knowledge map approach to analyzing the level of knowledge convergence in a CSCL context. The results indicated that the activation quantity of the common knowledge map can be adopted to measure the level of knowledge convergence. In addition, knowledge convergence can significantly predict group performance in a CSCL context. Furthermore, the knowledge map approach is also an effective method for quantifying the level of knowledge convergence. Thus, group performance can be assessed through the lens of knowledge convergence. Knowledge convergence serves as a vehicle which is able to shed light on the nature of collaborative learning. Knowledge convergence can also provide insights into how group members influence each other. The main contribution of this study is to propose a new analytical method and an effective indicator for measuring the level of knowledge convergence in CSCL settings.

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Part II
Co-regulation and Socially Shared Regulation in Computer-Supported Collaborative Learning

Chapter 4
Analysis of Co-regulation Behavioral Patterns by Cluster and Sequential Analysis in CSCL

Abstract Computer-supported collaborative learning (CSCL) has been widely adopted in the field of education. Many benefits from collaborative learning have been well documented in the literature. Both collaborative knowledge building and regulation are very crucial for successful collaborative learning. This study focuses on how group members co-regulate each other in a CSCL environment. The online discussion transcripts of 24 groups were analyzed based on the coding scheme. The cluster analysis and sequential analysis method were integrated to analyze the behavioral patterns of co-regulation. It is found that students demonstrated different characteristics of co-regulation in terms of behavioral patterns and behavioral transitions. Few groups made adaptation during co-regulation. The implications for developers and practitioners are also discussed in detail.

Keywords Co-regulation · Co-regulated learning · Behavioral pattern · Cluster analysis · Sequential analysis · CSCL

4.1 Introduction

Collaboration with others has been considered as a central form of human activity (Barron 2009). A lot of the benefits of collaboration have been addressed in previous studies. For example, learning occurs through collaboration with others in school settings or in informal contexts (Barron 2009). Social communication skills can be fostered by collaborating with others during the processes of resolving discrepancies, negotiating issues, and achieving common understanding (Roschelle 1992). Constructive dialog during the process of collaboration can also promote conceptual development and social interaction (Barron 2009; Roschelle 1992). Therefore, collaboration is very crucial for human development.

Co-regulation is defined as an externally initiated regulatory process that promotes self-regulation and shared cognition (Zheng and Huang 2016). Previous studies have indicated that co-regulation is important for productive and successful collaborative learning (Winne et al. 2013). Group members have to co-regulate their

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tasks and social interactions through setting goals, making plans, selecting and enacting strategies, monitoring, as well as evaluating and reflecting. Co-regulation emphasizes the social interactions that occur between two or more group members in a collaborative learning context (Zheng and Yu 2016).

It has been found that co-regulation can support and promote self-regulated learning to a large extent (Chan 2012). Contemporary research has paid more attention to self-regulated learning, while little effort has been put into examining co-regulated learning in the field of education. Failing to consider the crucial role of co-regulated learning leaves a gap between co-regulation and collaboration. This gap must be addressed so as to provide researchers access to how learners conduct collaborative learning through the lens of co-regulation. This study aims to analyze how group members co-regulated their learning in a CSCL environment. This CSCL environment supports co-regulation through setting goals, making plans, online discussions, selecting strategies, evaluation, and reflection. The following section will describe this process in detail.

4.2 Literature Review

4.2.1 Regulated Learning

Regulated learning involves intentionally negotiating task goals, selecting and enacting strategies to optimize task performance, monitoring progress, as well as making adaptations (Järvelä and Hadwin 2013). Researchers posited that regulated learning is intentional and goal directed, meta-cognitive, and social (Hadwin et al. 2011). Usually, researchers only centered on knowledge building without focusing on how group members regulate each other in CSCL. In fact, regulated learning is more important than knowledge building to some extent. In addition, knowledge building is different from regulated learning in the following ways. First, knowledge building involves sharing information, transforming information, and integrating new information with prior knowledge through social interactions (Mayer 1996; Resnick et al. 1991). Therefore, knowledge building focuses on domain knowledge and task-related aspects, while regulated learning covers socio-cognitive and team related aspects (Fransen et al. 2013). Second, the target information of knowledge building and regulated learning are different. In terms of knowledge building, domain knowledge is constructed by group members. With regard to shared regulation, meta-motivation, meta-emotion, and meta-cognition knowledge is constructed during a collaborative learning process (Järvelä and Hadwin 2013). All in all, knowledge building and regulated learning interact with each other. Regulation of motivation, emotion, goals, plans, and strategies can promote knowledge building, and vice versa.

There are three forms of regulated learning, namely self-regulated learning, co-regulated learning, and socially shared regulation of learning (Järvelä and

Hadwin 2013). In a collaborative learning context, each group member needs to regulate his or her learning (self-regulated learning), other members' learning (co-regulated learning), as well as collectively regulate all members' learning (socially shared regulation of learning). Self-regulated learning is the process that promotes individuals to set goals, make plans, adopt strategies, monitor, and evaluate (Schunk and Zimmerman 2008). Winne et al. (2013) posited that successful collaborative learning required each group member to regulate his or her own learning well. However, researches also indicated that students are self-regulated but do not regulate each other (Winters and Alexander 2010).

As the expansion of self-regulated learning, co-regulated learning implies multiple self-regulating agents socially regulating each other's learning processes (Volet et al. 2009). Co-regulated learning requires every group member to be aware of one another's progress and be able to regulate each other. Co-regulatory abilities have been considered as important abilities for improving the quality of collaborative learning (Ucan and Webb 2015). However, productive collaborative learning requires more than self-regulated learning and co-regulated learning (Järvelä and Hadwin 2013), namely socially shared regulation.

Socially shared regulated learning implies the construction and maintenance of collectively shared regulatory processes, beliefs, and knowledge to achieve a shared understanding (Hadwin et al. 2011). Findings indicated that socially shared regulated learning plays a crucial role in collaborative learning (Rogat and Linnenbrink-Garcia 2011). Group members need to jointly negotiate and regulate their motivation, beliefs, emotions, goals, plans, and strategies to formulate shared outcome in CSCL.

4.2.2 About Co-regulation

Self-regulation is defined as an active and constructive process in which learners regulate their motivation, cognition, meta-cognition, emotion, and behavior (Pintrich 2000). Co-regulation extends self-regulation by socially regulating each other's learning (Volet et al. 2009). Co-regulation is fundamental for the establishment of joint understanding or mutual knowledge (Barron 2009). As a central process, co-regulation requires group members to coordinate each other's motivation, emotion, cognition, and meta-cognition by questioning, prompting, explaining, and restating (Järvelä and Hadwin 2013).

Co-regulation is grounded by Vygotsky's (1978) theory that higher psychological processes in individuals originate from social interactions. Co-regulation consists of emergent interactions mediated by goal setting, planning, monitoring, and evaluation (Zheng and Huang 2016). Co-regulation also describes interactions between two or more peers that coordinate self-regulated learning processes (McCaslin and Hickey 2001). For example, student A set his or her goal based on the task standard. Student B questioned the goal after discussion. Thus, student A evaluated and reflected his or her goal. Finally, if student A had the ability of co-regulation, he or she will make adaptation of the goal. In this scenario, co-regulation was mediated by social interaction between the two members. Therefore, co-regulation was externally initiated by others.

4.2.3 Co-regulation in CSCL

CSCL centers on how people can learn together with the help of computers (Stahl et al. 2006). Koschmann (2002) posited that CSCL is centrally concerned with meaning and the practices of meaning making in the context of joint activity. During collaborative learning, co-regulation can be achieved by interacting with other group members. Group members need to co-regulate each other to achieve common ground and shared understanding or outcomes. For example, group members can ask questions or explain reasons, relationships, or mechanisms during collaborative learning. If they have conflicts, they can negotiate with each other and find solutions. Finally, they will reach a shared understanding of the subject matter. Hadwin et al. (2011) posited that co-regulation occurred when individuals' regulatory activities were supported, guided, or restricted by others. Moreover, Volet et al. (2009) indicated that high-level co-regulation contributed to productive collaborative learning.

Previous studies have explored how group members co-regulated one another in a CSCL context. DiDonato (2013) suggested that co-regulated learning processes in a CSCL context may lead to increases in self-regulated learning and co-regulated learning. Lajoie and Lu (2011) examined the influence of an external tool on co-regulated learning activities. They found that an interactive whiteboard demonstrated better learning outcomes than a traditional whiteboard. So the interactive whiteboard served as an external tool to facilitate co-regulated learning.

However, previous studies put more emphasis on examining how students adopted strategies rather than the regulation of collaboration (Winters and Azevedo 2005). Few studies have investigated how group members co-regulated one another during collaborative learning. Furthermore, few tools to support co-regulation have been developed. The purpose of this study is twofold. First, it aims to develop a system to support co-regulation in a CSCL context. Second, it examines the behavioral pattern of co-regulation in the co-regulated learning environment to gain more insights into the nature of co-regulation. Thus, research questions are formulated as follows:

1. How many potential clusters can be formed based on co-regulated learning behavioral traits in a technology enhanced co-regulated environment?
2. What are the behavioral sequence characteristics of each cluster?

4.3 Method

4.3.1 Participants

The number of participants in this study was 96 undergraduates (73 female and 23 male) with an average age of 18 from a university in Beijing. They were freshmen in the departments of Law and Chinese Language and Literature. They were randomly assigned into 24 groups of 4 people. The collaborative learning task was to design a plan about how to set up a wireless network in the dormitory. All of the groups completed the same task for about 2 h.

4.3.2 Procedure

This study was conducted as part of a study course on the fundamental application of computers, a course worth three academic credits. The collaborative learning task was to design a plan to set up a wireless network in a student dormitory. In the study, 24 groups completed the same task within 2 h in two computer classrooms. All of them conducted online collaborative learning via a CSCL environment. Figure 4.1 shows a screen shot of the CSCL platform. This CSCL platform can support students whilst setting their goals, making plans, discussing online, submitting group products, as well as evaluating and reflecting. Before collaborative learning, the research assistant first introduced the platform and the operation method. Subsequently, every group conducted online collaborative learning for 2 h.

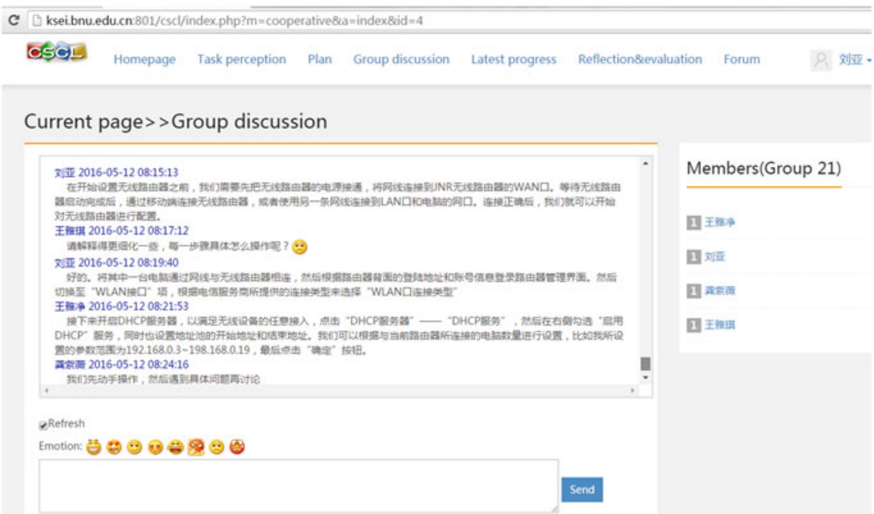

Fig. 4.1 A screen shot of online discussion

Members of the same group were located in different classrooms and were not permitted face-to-face discussion. Each group was uninterrupted unless they required help with use of the platform. All of the discussion transcripts were recorded automatically by the platform.

4.3.3 Data Analysis

This study integrated content analysis, lag sequential analysis (LAS), and cluster analysis to analyze the behavioral pattern of co-regulated learning in a CSCL environment. Table 4.1 shows the coding scheme for co-regulation that was developed by Zheng and Huang (2016). There were six kinds of co-regulated learning behavior, including goal orientation, making plans, enacting strategies, monitoring and controlling, evaluating and reflecting, as well as adapting meta-cognition. Off-topic was also considered because group members often discussed some topics which were irrelevant to the collaborative learning tasks. The analysis unit was the speaker's turn. Two graduates were trained to code the data by researchers, and independently coded all of the data manually. In order to ensure consistency, Cohen's Kappa was calculated using SPSS software. The result indicated that a Kappa coefficient of 0.81 was achieved, which demonstrated excellent reliability (Viera and Garrett 2005). Finally, all discrepancies were discussed and resolved.

Cluster analysis was then performed to analyze the students' coded behavior using SPSS 20.0. The cluster analysis process included two steps. First, hierarchical cluster analysis was conducted to determine the number of clusters. Second, *k*-mean cluster analysis was performed to analyze the characteristics of the behaviors.

Table 4.1 The coding scheme for co-regulation in CSCL

Dimension	Examples
Goal orientation (GO)	"This task requires us to set up wireless network"
Making plans (MP)	"We need to make a schedule in order to complete this task"
Enacting strategies (ES)	"I have an idea. We can search for information via the Internet, and then compare which one is better"
	"You needn't argue anymore. I think I can find out a solution"
Monitoring and controlling (MC)	"How is it going? We only have one hour left"
	"I think we will have trouble with this solution"
Evaluating and reflecting (ER)	"I think we need to reflect the current plan"
	"Overall, we have achieved the expected goal and finished the task successfully"
Adapting meta-cognition (AM)	"We need to adapt our plan and strategies immediately"
Off-topic (OT)	"We will have dinner after discussion"

In this study, LSA (Bakeman and Gottman 1997) was also adopted to analyze the behavioral transition of co-regulated learning. The sequential analysis was adopted in previous studies to analyze user behavioral patterns (Hou and Wu 2011; Hou and Li 2014). There were three steps during the LSA process. First, to calculate the frequency of each kind of behavior. Second, to analyze the transition matrix of behavioral frequency. Third, to calculate the adjusted residuals (Bakeman and Gottman 1997). Generalized Sequential Querier (GSEQ) software, version 5.1, was adopted to conduct LSA.

4.4 Results

4.4.1 Cluster Patterns of Co-regulated Learning Behavior

In order to examine the cluster patterns of co-regulated learning behavior, the hierarchical clustering Ward method was adopted. The results indicated there were three clusters in terms of co-regulated learning behavior patterns. Then *k*-mean cluster analysis was conducted to examine the characteristics of each cluster. Table 4.2 shows the cluster analysis results and the average frequency of each kind of behavior.

As shown in Table 4.2, the three clusters comprise 3 (12.5 %), 16 (66.7 %), and 5 (20.8 %) groups, respectively. It was found that co-regulated learning behaviors of Cluster 3 achieved the highest frequency in terms of making plans, enacting strategies, monitoring and controlling, evaluation and reflection, as well as adapting meta-cognition. While Cluster 1 achieved the lowest frequency with respect to goal orientation, making plans, enacting strategies, monitoring and controlling, evaluation and reflection, as well as adapting meta-cognition. The co-regulated learning behaviors of Cluster 2 achieved a medium level. In addition, the off-topic messages of cluster 1 accounted for the highest proportion, while the off-topic discussion of Cluster 3 accounted for the lowest proportion. Overall, goal orientation, making plans, enacting strategies, monitoring and controlling, as well as evaluation and reflection were the five main behaviors.

Table 4.2 Cluster analysis of group behavior

Behaviors	Cluster 1 (*N* = 3, 12.5 %)	Cluster 2 (*N* = 16, 66.7 %)	Cluster 3 (*N* = 5, 20.8 %)
GO	5	18	15
MP	2	11	18
ES	22	102	123
MC	23	97	151
ER	4	15	24
AM	1	1	3
OT	103	86	56

4.4.2 Sequential Patterns of Co-regulated Learning Behavior

In order to examine the sequential pattern of each cluster, sequential analysis of the seven behaviors codes (GO, MP, ES, MC, ER, AM, and OT) of all three clusters was conducted using GSEQ 5.0. Table 4.3 shows the adjusted residuals for the three clusters. The rows represent the initial behaviors and the columns represent the behaviors which followed the initial behaviors. If a *z*-score was greater than 1.96, it indicated that the connectivity of the sequence achieved a significant level (Bakeman and Gottman 1997). Figures 4.2, 4.3, and 4.4 demonstrated the behavioral transition diagrams of Cluster 1, Cluster 2, and Cluster 3, respectively.

According to the analysis results in Table 4.3, and Figs. 4.1, 4.2, and 4.3, it was found that students' co-regulated learning behaviors were significantly different. In terms of Cluster 1, only three behavioral sequences achieved a significant level

Table 4.3 The adjusted residual table for the three clusters' behaviors

Z	GO	MP	ES	MC	ER	AM	OT
Cluster 1							
GO	−0.41	−0.26	0.41	1.81	−0.41	−0.18	−1.19
MP	−0.26	−0.16	−0.57	1.55	−0.26	−0.11	−0.45
ES	−0.91	1.50	1.32	1.44	1.73	−0.40	−2.55
MC	1.66	−0.58	1.20	1.32	−0.93	−0.41	−1.87
ER	−0.36	−0.23	2.13*	0.71	−0.36	−0.16	−1.70
AM	−0.18	−0.11	2.51*	−0.39	−0.18	−0.08	−1.37
OT	−0.21	−0.43	−2.95	−3.19	−0.21	0.75	4.52*
Cluster 2							
GO	1.38	0.54	1.64	0.02	−1.02	−0.24	−2.08
MP	0.74	−0.63	1.59	−0.02	−0.79	5.39*	−2.03
ES	−0.94	−0.93	0.24	1.57	2.56*	−0.67	−2.21
MC	1.50	−0.16	2.21*	1.15	−1.64	−0.65	−3.24
ER	−0.87	0.74	−1.62	1.69	2.66*	−0.22	−1.20
AM	−0.22	−0.19	−0.69	−0.62	4.30*	−0.06	−0.60
OT	−1.15	0.79	−3.18	−3.57	−1.95	−0.59	8.24*
Cluster 3							
GO	0.65	−0.87	0.15	1.21	−1.01	−0.35	−0.91
MP	−0.84	−0.96	1.21	1.53	−1.11	−0.38	−1.82
ES	−2.00	−0.87	1.92	1.05	−0.26	−1.18	−1.93
MC	2.00*	1.50	−0.14	0.41	−0.99	−0.19	−1.59
ER	−0.98	−1.11	−0.26	−0.10	1.34	−0.45	0.85
AM	−0.34	−0.38	−1.18	−0.18	−0.45	13.11*	−0.73
OT	0.77	0.97	−2.69	−3.42	2.14*	−0.71	5.95*

*$p < 0.05$

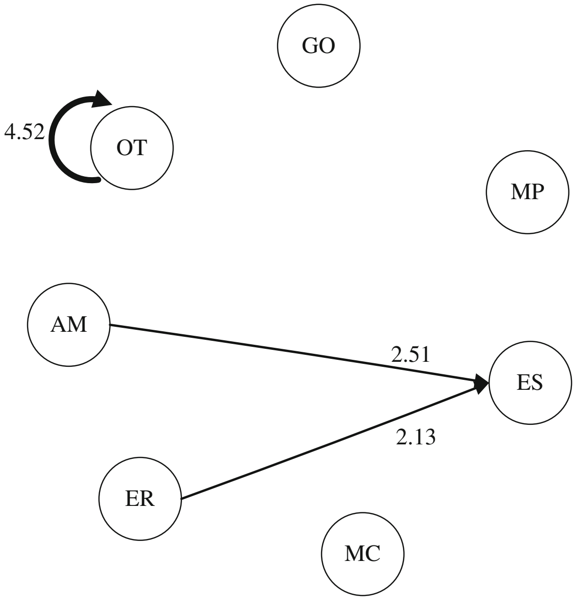

Fig. 4.2 The behavioral transition diagram of cluster 1

(ER → ES, AM → ES, and OT → OT). The behavioral path ER → ES showed that when group members evaluated and reflected, they tended to enact strategies. The behavioral path AM → ES demonstrated that when group members adapted

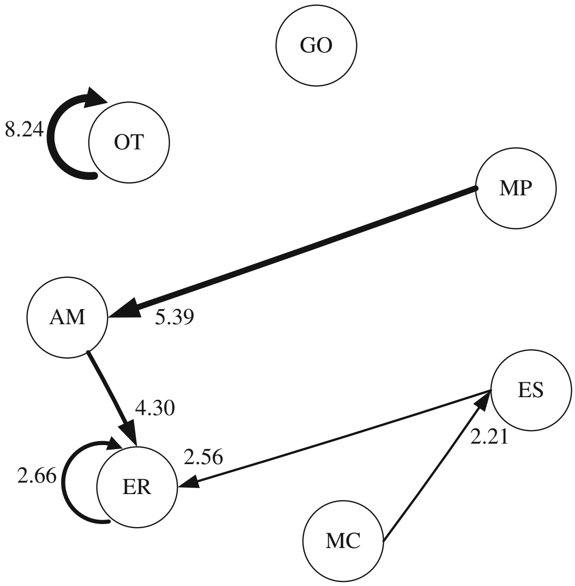

Fig. 4.3 The behavioral transition diagram of cluster 2

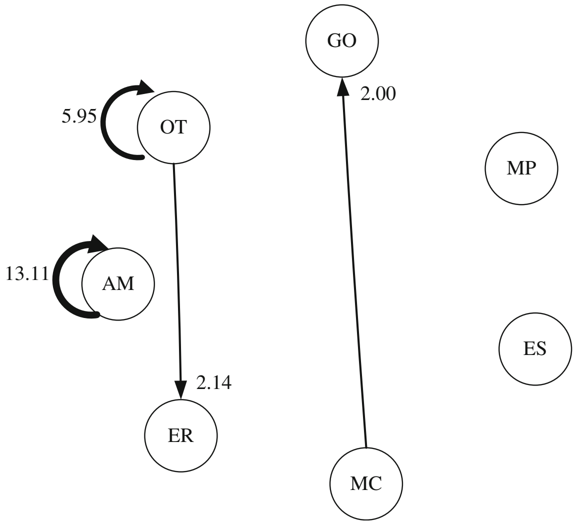

Fig. 4.4 The behavioral transition diagram of cluster 3

meta-cognition, they continued to enact strategies. These two paths should be encouraged because they can promote group members to co-regulate themselves. While the behavioral path OT → OT showed that when some group members talked about irrelevant topics, other students joined in with that chat. This means that the groups in Cluster 1 cannot co-regulate their learning. It also indicated that only a few behavioral transitions occurred in Cluster 1.

With respect to Cluster 2, six behavioral paths reached a significant level (MP → AM, AM → ER, ES → ER, MC → ES, ER → ER, and OT → OT). It was very clear that five different behavioral paths emerged in Cluster 2. The behavioral path MP → AM indicated that when group members made a plan, they tended to adapt meta-cognition. The behavioral path AM → ER demonstrated that when group members adapted meta-cognition, they continued to evaluate and reflect. The behavioral path ES → ER indicated that when group members enacted strategies, they continued to evaluate and reflect. The behavioral path MC → ES showed that group members enacted strategies when they monitored and controlled their learning processes. The behavioral path ER → ER revealed that when some group members evaluated and reflected, others continually evaluated and reflected. While the behavioral path OT → OT was the same as in Cluster 2. This indicated that group members of Cluster 2 also talked about some irrelevant topics. Furthermore, this kind of behavior continually occurred among group members of Cluster 2. Overall, more behavioral transition occurred in Cluster 2. This result indicated that the groups of Cluster 2 can better co-regulate one other.

With regard to Cluster 3, only four behavioral sequences reached a significant level (MC → GO, AM → AM, OT → ER, and OT → OT). The behavioral path MC → GO indicated that group members oriented their goals when they monitored

Table 4.4 Frequency and distribution of co-regulation behaviors

	GO	MP	ES	MC	ER	AM	OT
Frequency	38	31	247	271	43	5	245
Percentage (%)	4.3	3.5	28.1	30.8	4.9	0.6	27.8

learning processes. The behavioral path AM → AM showed that when some group members adapted their meta-cognition, others followed to adapt their own. The behavioral path OT → ER indicated that when some group members talked about irrelevant topics, other group members regulated to evaluate and reflect. At the same time, the behavioral path OT → OT also occurred. This result indicated that some groups cannot regulate themselves and off-topic discussion continually occurred in some groups. Among these four behavioral paths, the behavioral paths MC → GO and OT → ER were desirable and should be encouraged. Overall, Cluster 2 demonstrated the best co-regulated learning behaviors among the three clusters because more behavioral sequences occurred in Cluster 2.

In addition, the behavioral transition pattern of 24 groups were examined by the sequential analysis method. Table 4.4 shows the frequency and distribution of different co-regulation behaviors. It was found that monitoring and controlling accounted for the highest percentage, followed by enacting strategies, while making adaptations occurred the least. These results indicated that students could enact strategies and monitor learning processes. However, they seldom made adaptions of meta-cognition during co-regulation.

Table 4.5 shows the adjusted residual of co-regulation behaviors. Figure 4.5 shows the behavioral transition diagram of all groups. As shown in Fig. 4.5, there were eleven statistically significant behavioral paths. They were MP → ES, MP → AM, ES → MC, ES → ER, ES → ES, MC → ES, MC → MC, MC → GO, ER → ER, AM → AM, and OT → OT. Among these behavior transitions, MP → ES, MP → AM, ES → MC, ES → ER, MC → ES, and MC → GO were desirable and within expectations. However, five paths, namely ES → ES, MC → MC, ER → ER, AM → AM, and OT → OT, indicated group members could not regulate each other very well. This revealed that some group members repeated other members' behaviors continually.

Table 4.5 The adjusted residual table for the 24 groups

Z	GO	MP	ES	MC	ER	AM	OT
GO	1.32	−0.30	1.51	1.34	−1.48	−0.48	−2.50
MP	−0.19	−1.08	2.07*	1.91	−1.33	2.00*	−3.17
ES	−2.16	−0.69	2.53*	2.86*	2.05*	−1.40	−5.02
MC	2.85*	1.37	2.33*	2.45*	−1.69	−0.52	−5.67
ER	−1.35	−0.44	−0.45	1.44	2.64*	−0.51	−1.46
AM	−0.45	−0.43	−0.43	−0.48	1.49	11.76*	−1.41
OT	−0.57	0.15	−6.18	−7.39	−0.61	−0.39	14.24*

*$p < 0.05$

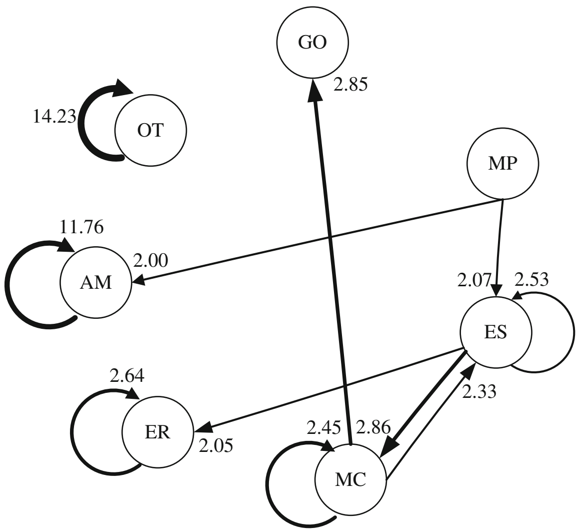

Fig. 4.5 The combined behavioral transition diagram of all groups

4.5 Discussion

In this study, cluster analysis and behavioral sequence analysis was conducted to examine the characteristics of co-regulated learning behaviors in a CSCL environment. The cluster analysis helped to identify the potential cluster patterns of group members' various behaviors. Sequential analysis of the behavioral patterns was adopted to examine learners' behavioral sequences in the field of digital learning (Hou and Wu 2011). This study considered both the behavioral frequency and sequential patterns in order to get a better understanding of group members' co-regulated learning behaviors.

It was found that Cluster 3 displayed the highest proportion in terms of co-regulated learning behavioral frequency and Cluster 1 demonstrated the lowest. Cluster 2 was characterized by a medium level of co-regulated learning behavior frequency. However, adapting meta-cognition occurred the least among all of these clusters. This means group members cannot make adaptations to their meta-cognition during learning processes. According to Winne and Hadwin (1998), learners need to make major adaptations by revising or restructuring cognitive conditions, meta-cognitive strategies, and operations to complete tasks. A lack of ability to adapt meta-cognition will hinder the processes of co-regulated learning. Overall, the following co-regulated learning behaviors achieved higher percentages: orientating goals, making plans, enacting strategies, monitoring and controlling, as well as evaluation and reflection. This result indicated that group members can regulate each other by establishing goals, making plans, selecting and applying strategies, monitoring their learning processes, as well as evaluating and reflecting upon learning outcomes.

The results of the analysis of behavioral sequence indicated that different clusters demonstrated different behavioral sequences. About 66.7 % of the groups could co-regulate themselves by behavioral transitions of making plans, enacting strategies, evaluating and reflecting, as well as adapting meta-cognition. These 16 groups displayed better co-regulated learning behaviors than other groups. Overall, the behavioral paths ER → ES, AM → ES, MP → AM, AM → ER, ES → ER, MC → ES, MC → GO, and OT → ER were desirable paths which should be encouraged, because group members need to co-regulate themselves via different behaviors. That is to say behavioral transitions are necessary for co-regulated learning.

In addition, the behavioral path OT → OT occurred in each cluster. This result indicated that students discussed some irrelevant topics and tended to fall into repetitive cycles. In fact, some off-topic discussion may smooth the collaborative-learning processes and serve the latent function of guiding group discussion (Chen and Wang 2009). For example, cheers, encouragement, or greetings can help to create a harmonious atmosphere. However, if group members continually talk about irrelevant topics, it can be considered a waste of time which may hinder the co-regulated learning processes.

This study has several implications for designers and developers in the field of education. First, the sequential analysis method can help instructional designers get a better understanding of the actual behaviors and co-regulated learning behavioral patterns of group members. The behavioral transition diagram visualizes different behavioral sequences, thus gaining more insight into how group members regulate each other in a CSCL environment. Thus, the interaction processes in collaborative learning were discovered through in-depth analysis of behaviors. Second, it was found that off-topic discussion occurred frequently during collaborative learning. Therefore, it is very necessary to adopt semantic analytical technologies to detect off-topic discussion and remind learners to return to collaborative learning tasks. Third, teachers should intervene when students show that they cannot co-regulate themselves based on their behavioral patterns and status. Therefore, developers can design useful tools to automatically analyze behavioral sequence transitions.

4.6 Conclusion

This study analyzed the behavioral pattern of co-regulation in a CSCL environment. Cluster analysis and sequential analysis methods were adopted to examine the characteristics of co-regulation. The results indicated that group members could co-regulate each other by setting goals, making plans, enacting strategies, monitoring and controlling, as well as making adaptations. However, making adaptations occurred the least among all of the kinds of co-regulation behaviors. Twenty-four groups demonstrated 3 clusters based on co-regulation behaviors. Every cluster displayed different traits of behavioral transition.

This study has several limitations. First, this study only analyzed the behavioral pattern of co-regulation. How group members regulated themselves and socially shared regulated joint learning activity has not been examined. Future studies will examine socially shared regulation in a CSCL context. Second, the study manually coded all of the discussion transcripts. This was very time consuming. Future studies will explore how to automatically analyze the data. Third, only one task was completed in this study. It may be that the task context influences how students co-regulated one other. Future studies will examine the traits of co-regulation in other task contexts.

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Chapter 5
Analysis of Socially Shared Regulation in CSCL

Abstract An increasing number of studies show that socially shared regulation is very crucial for successful and productive collaborative learning. However, the elaborate analysis of behavioral patterns of socially shared regulation remains lacking in a CSCL context. This study aims to examine the behavioral pattern characteristics of socially shared regulation in a CSCL environment. In this study, 41 college students participated and they were randomly assigned into 13 groups of 3 or 4 people. All of the group members completed an instructional design plan using the online collaborative learning platform. Content analysis and LSA methods were adopted to analyze the discussion transcripts. The results indicated that group members can socially regulated their behaviors to orientate goals, make plans, monitor the collaborative learning processes, evaluate solutions, and make adaptations. However, high-achievement groups perform better than low-achievement groups regarding their socially shared regulation abilities. The implications for teachers and developers as well as for future studies are also discussed.

Keywords Socially shared regulation · Behavioral pattern · CSCL

5.1 Introduction

With the development of educational technology, many benefits of CSCL are well-documented and demonstrated in educational research. Learners benefit from collaborative learning because of productive interactions (Dillenbourg 1999), knowledge building (Bereiter and Scardamalia 2003), and mutual regulation (Blaye and Light 1990). Previous studies revealed that successful collaborative learning depends on many conditions, such as a CSCL environment (Stahl et al. 2006), task characteristics (Schellens et al. 2007), teachers' intervention (Van Leeuwen et al. 2013), scripts (Dillenbourg 2002), and so on.

Recently, regulatory challenges have emerged and have been presented to students in collaborative learning groups (Iiskala et al. 2011; Lee et al. 2014). Within CSCL contexts, group members need to jointly regulate their goals, plans,

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and strategies (Järvelä et al. 2010) to maintain a shared understanding of the subject matter. However, there is limited research investigating how group members collectively regulate in CSCL contexts. This study proposes that the consideration of socially shared regulation in CSCL can offer valuable and important insights into the nature of collaborative learning.

5.1.1 Regulation in a CSCL Context

Strategically regulating one's own learning and that of others is viewed as one of the important skills in the 21st century (Järvelä et al. 2014). Previous studies indicated that strategically planning and adapting one's learning requires the ability to tactically regulate oneself (i.e., self-regulated learning, SRL), others (i.e., co-regulated learning, CoRL), and a whole group (i.e., socially shared regulated learning, SSRL) (Hadwin et al. 2011; Winne et al. 2013). The main difference between these three kinds of regulation is who is regulating during the learning processes. Self-regulation is described as an individual process in which one regulates his/her own learning in order to improve academic performance (Zimmerman 2008). Co-regulation focuses on an individual's attempt to regulate others' cognition, meta-cognition, motivation, and emotion (Järvenoja et al. 2013). Socially shared regulation emphasizes all group members jointly regulating collective activities (Järvelä and Hadwin 2013). Self-regulation, co-regulation, and socially shared regulation of learning can contribute to successful collaborative learning.

In a CSCL context, it is more crucial to regulate others' cognition, motivation, emotion, and behavior as well as that of the whole group. This is because collaborative learning means to co-construct shared understanding via interaction with group members (Roschelle and Teasley 1995). It is also important to regulate goals, plans, and strategies to foster productive collaborative learning. Drawing on the information processing models of SRL, regulated learning involves defining tasks, setting goals and planning, enacting tactics, and adapting to meta-cognition (Winne and Hadwin 1998). Defining the task means that learners generate perceptions of the task. Setting goals and planning refers to frame goals and planning in order to achieve them. Enacting tactics includes selecting and applying strategies during learning processes. Adaptation to meta-cognition means that learners make major adaptations under their control (Winne and Perry 2000).

5.1.2 Socially Shared Regulation in CSCL

Successfully collaborating in a CSCL context requires collective or shared regulation. Shared regulation occurs when group members co-construct shared task perceptions or shared goals and plans (Järvelä and Hadwin 2013). Socially shared regulation of learning refers to processes by which group members jointly regulate their collective activities (Järvelä and Hadwin 2013). Socially shared regulation of learning involves the construction and maintenance of collectively shared regulatory processes, knowledge, and beliefs (Hadwin et al. 2010).

In a CSCL context, a group needs to regulate beliefs, motivations, emotions, plans, strategies, resources, and efforts to achieve shared goals. The previous studies indicated that the high quality of collaborative learning relies on the abilities to cyclically regulate group activities (Erkens et al. 2005). Failure to coordinate group activities will result in negative outcomes, such as social loafing or the sucker effect (Kwon et al. 2014). Furthermore, it is necessary to establish a shared common ground for students who work in a collaborative learning group. There are two strategies for establishing common ground, one is adapting to partners, and the other is to ensure joint attention when needed (Janssen et al. 2010). However, the timing of maintaining common ground depends on the task and group members. The previous research suggested that early group regulation is helpful with establishing shared common ground and enhanced shared understanding (Lajoie and Lu 2011).

Group coordinated and regulating behaviors are essential for the whole group to work. However, learners cannot exhibit these kinds of abilities as you would expected in some cases (Puntambekar 2006). Therefore, group regulatory behaviors need to be initiated and facilitated by group members' autonomy or teachers' intervention. However, which kind of regulatory behavior can affect successful collaboration is still unclear. This study aims to investigate the behavior pattern of socially shared regulation in CSCL so as to identify which one can contribute the most to successful and productive collaborative learning. The research questions are addressed as follows:

1. What are the behavioral characteristics of socially shared regulation?
2. Do any differences exist in the behavioral patterns of socially shared regulation between high- and low-achievement groups?

5.2 Method

5.2.1 Participants

In this study, 41 students majoring in history participated. Of these, 29 % of them were male and 71 % of them female. This study was conducted in the information communication technology (ICT) course, integrated into K-12, worth two academic credits. All of the participants were enrolled in the ICT course for the first time. In order to create probabilistically equivalent groups, all of the participants were randomly divided into 13 groups of 3 or 4 people. They all had experience about collaborative learning from previous courses.

5.2.2 Experimental Procedure

The study was conducted in two phases. In the first phase, all of the participants took a one-day course about how to integrate ICT. In the second phase, all of them conducted online collaborative learning for 3 h via a platform that supported collaborative learning. Every group needed to complete the same collaborative learning task online. The collaborative learning task was about instructional design in a flipped classroom. The topic of instruction was about farm life in a primitive society, which was taught in Grade 7. The group product was an instructional design plan. Every group member needed to discuss how to design and implement this topic using ICT. In order to facilitate socially shared regulation, students needed to set a goal at first, and then make a plan and select appropriate strategies. They could monitor the whole collaborative learning process and make adaptations when necessary. All of the discussion logs were automatically recorded via our platform. Therefore, it was feasible to analyze the behavioral pattern of socially shared regulation.

5.2.3 Data Analysis

In order to analyze discussion transcripts of 13 groups, a content analysis method was adopted in this study. The coding scheme proposed by Zheng and Huang (2016) was adapted in order to analyze the behavioral pattern of socially shared regulation, as shown in Table 5.1. The data analysis included two phases. The first phase was to conduct content analysis. The episode was chosen as the unit for analysis. The episode consisted of pieces of dialogue that shared the same focus and a joint regulation of the activity within the group (Grau and Whitebread 2012). Two raters independently coded all of the discussion transcripts based on the scheme. In order to determine the inter-rater reliability, Cohen's kappa was adopted to calculate the coding results. Cohen's kappa achieved a score of 0.81. All of the discrepancies were discussed and solved face-to-face. In the second phase, LSA (Bakeman and Gottman 1997) was conducted using GSEQ 5.1. In this study, LSA was mainly used to investigate the probability of behavioral occurrence (Hawks 1987). This method has been adopted in past studies in order to analyze behavioral patterns (Hou 2015; Yang et al. 2015).

5.3 Results

5.3.1 Analysis of the Behavioral Characteristics of Socially Shared Regulation

Behavior frequency analysis of socially shared regulation

In order to analyze the behavioral characteristics of socially shared regulation, the frequency and distribution of each kind of behavior were calculated, as shown in

Table 5.1 The coding scheme of socially shared regulation

The first-level category	The second-level category	Examples
Orientating goals	Establishing task demands and setting goals (ES)	"This collaborative learning task is to conceive an instructional design in a flipped classroom setting"
Making plans	Making plans about how to reach goals, including selecting strategies, setting timelines, and so on (MP)	"We need to make a schedule about our task immediately"
	Negotiating the division of labor (ND)	"I think we need to discuss about the division of labor"
Enacting strategies	Advancing and explaining solutions (AE)	"Let me explain this solution by examples"
	Coordinating conflicts (CO)	"As a group leader, I can coordinate the conflicts soon"
Monitoring and controlling	Monitoring or controlling the whole group progress (MC)	"Everyone needs to be responsible for the collaborative learning task. Otherwise we can't finish it on time"
	Claiming (partial) understanding or Comprehension failure (CC)	"Both of us cannot understand what you have said. Can you explain it in detail?"
	Detecting errors or checking plausibility (DC)	"We need to check the feasibility of our instructional design plan now"
Evaluating and reflecting	Evaluating current solutions (EV)	"The current plan is difficult to implement because students have no enough time to visit the museum"
	Reflecting on the group goals and progress (RE)	"Now it is time to reflect whether we have achieved the group goal"
Adapting meta-cognition	Making adaptions to goals, or plans, or strategies (MA)	"Maybe we need to revise our strategies so as to complete the task on time"
Off-topic	Messages irrelevant to the discussion task (OT)	"After we submit our group product, we will have lunch together"

Table 5.2 Frequency and distribution of behavioral codes

	ES	MP	ND	AE	CO	MC	CC	DC	EV	RE	MA	OT
Frequency	23	56	30	141	15	32	110	24	63	13	22	97
Percentage (%)	3.7	8.9	4.8	22.5	2.4	5.1	17.6	3.8	10.1	2.1	3.5	15.5

Table 5.2. It was very clear that the most frequent behavior was advancing and explaining solutions, which accounted for 22.5 %. This indicated that learners could advance their solutions during collaboration. Claiming (partial) understanding or comprehension failure (CC) accounted for 17.6 %. They could also claim comprehension failure when they did not understand what group members

discussed. However, the off-topic discussion accounted for 15.5 %, which revealed that sometimes students discussed some topics that were not related to the collaborative learning. In addition, reflecting on the group goals and progress (RE, 2.1 %) occurred the least, which indicated that students seldom reflected upon whether they had achieved the goal.

Sequential analysis of socially shared regulation behavior

In order to analyze the behavior sequential characteristics of socially shared regulation, an LSA was conducted using GSEQ. Table 5.3 shows the adjusted residuals of all behavioral sequences. Only the Z-value of a sequence was above 1.96, the behavioral sequence was significant (Bakeman and Gottman 1997). Therefore, 11 behavioral sequences were significant based on Table 5.3. Figure 5.1 shows the transition diagram for the 11 significant behaviors. It is very clear that these socially shared regulation behaviors can be divided into 5 sections based on the sequential relationships between the behaviors. They were ES-MA-RE (establishing task demands and setting goals, making adaptions to goals, plans, or strategies, and reflecting on the group's goals and progress), ND-CC-AE-DC (negotiating the division of labor, claiming partial understanding, advancing and explaining solutions, and detecting errors or checking plausibility), MC-EV (monitoring or controlling group progress and evaluating current solutions), CO (coordinating conflicts), and OT (off-topic). In a word, all of the group members could socially regulate their behaviors in order to orientate goals, make plans, monitor collaborative learning processes, evaluate solutions, and make adaptations.

5.3.2 Comparison of Behavioral Sequences Between the High- and Low-Achievement Groups

In order to identify the high- and low-achievement groups, the group product was evaluated by the teacher at first. The instructional design plan was the final group product of each group. The top four groups were selected as high-achievement groups and the last four groups were considered the low-achievement groups based on the scores of the instructional design plan. Subsequently, frequency analysis and LSA were conducted so as to examine the behavioral differences between the high-achievement groups and low-achievement groups. Table 5.4 shows the frequencies of the socially shared regulation behavior of the low-achievement and high-achievement groups. As shown in Table 5.4, the higher proportion of socially shared regulation behaviors occurred in the high-achievement groups including establishing task demands and setting goals (ES), making plans (MP), advancing and explaining solutions (AE), coordinating conflicts (CO), evaluating current solutions (EV), reflecting on group goals and progress (RE), and making adaptions to goals, or plans, or strategies (MP). While negotiating the division of labor (ND),

Table 5.3 Adjusted residuals of all behavioral sequences

	ES	MP	ND	AE	CO	MC	CC	DC	EV	RE	MA	OT
ES	2.39*	−0.77	−0.12	−0.62	−0.77	−0.16	0.53	0.11	−0.93	0.84	2.48*	−0.88
MP	−1.55	1.02	−0.48	0.77	−1.24	−0.53	1.89	1.31	−0.77	−0.10	−1.51	−0.98
ND	−0.12	−1.09	3.06*	−2.59	−0.89	−0.44	2.81*	−1.13	−0.64	0.56	−1.08	1.28
AE	0.38	−0.79	−0.38	0.29	−1.51	−0.47	1.60	4.23*	0.91	0.18	−0.01	−3.55
CO	0.60	−1.22	−0.89	−1.50	17.99*	−0.90	−1.13	−0.79	−0.45	−0.55	−0.76	−1.66
MC	1.85	−1.09	−1.27	−1.25	−0.89	0.41	−0.63	−1.13	3.08*	0.56	0.93	0.23
CC	−0.03	−0.19	1.83	4.69*	−1.81	1.23	−1.12	−1.76	−1.03	−0.85	0.07	−3.07
DC	0.11	−0.08	−0.17	0.77	−0.79	−0.20	−0.12	1.14	−0.30	0.80	1.27	−1.53
EV	−0.18	0.82	−0.59	0.45	−0.41	−0.64	−0.20	−0.24	2.22*	−0.17	−0.11	−1.55
RE	−0.69	−1.09	−0.79	−0.50	1.33	1.85	−0.85	−0.71	0.76	1.61	2.46*	−0.67
MA	−0.92	1.68	−1.06	−0.40	0.70	−1.08	0.76	−0.94	1.38	−0.66	1.49	−1.35
OT	−0.90	1.47	−0.31	−3.03	−1.67	0.64	−3.11	−2.13	−2.79	−0.68	−2.03	11.48*

* $p < 0.05$

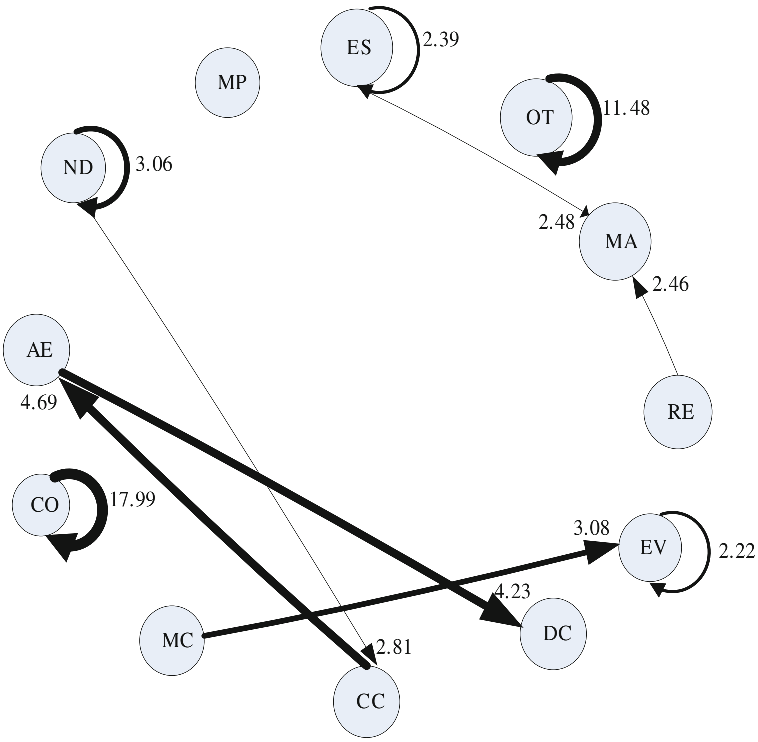

Fig. 5.1 Behavioral transition diagram for all participants

monitoring or controlling the whole group's progress (MC), claiming (partial) understanding or comprehension failure (CC), detecting errors or checking plausibility (DC), and off-topic discussion (OT) occurred more frequently in low-achievement groups.

Tables 5.5 and 5.6 show the adjusted residuals of low-achievement groups and high-achievement groups, respectively. In addition, Figs. 5.2 and 5.3 visualized the behavioral transition paths of the low-achievement groups and high-achievement groups. Overall, the high-achievement groups demonstrated more significant behavioral paths than low-achievement groups. The findings indicated that eight statistically significant behavioral paths occurred in the low-achievement groups, including ES → MA, MP → DC, RE → EV, CC → AE, MC → EV, MA → CC, ND → ND, and OT → OT. Eleven statistically significant behavioral paths occurred in the high-achievement groups, including MP → CC, ND → CC, ND → OT, AE → DC, CO → CO, MC → ES, CC → AE, EV → EV, RE → MA, OT → MP, and OT → OT.

Table 5.4 Frequencies of the socially shared regulation behavior of the low-achievement and high-achievement groups

	ES	MP	ND	AE	CO	MC	CC	DC	EV	RE	MA	OT
Low	5	9	8	26	0	8	22	6	7	2	1	31
	4 %	7.2 %	6.4 %	20.8 %	0	6.4 %	17.6 %	4.8 %	5.6 %	1.6 %	0.8 %	24.8 %
High	13	18	11	53	15	10	36	10	24	8	11	34
	5.4 %	7.4 %	4.5 %	21.8 %	6.2 %	4.1 %	14.8 %	4.1 %	9.9 %	3.3 %	4.5 %	14 %

Table 5.5 Adjusted residuals (low-achievement groups)

	ES	MP	ND	AE	CO	MC	CC	DC	EV	RE	MA	OT
ES	1.82	−0.65	−0.61	−1.19	0.00	−0.61	1.37	−0.52	−0.52	−0.30	4.84*	−0.21
MP	−0.65	−0.88	−0.83	0.06	0.00	0.56	0.40	2.48*	0.88	−0.40	−0.28	−0.94
ND	−0.61	0.56	2.17*	−0.64	0.00	−0.78	−0.38	−0.67	−0.67	−0.38	−0.27	0.93
AE	1.09	0.12	0.31	0.89	0.00	0.31	0.98	0.79	−0.25	1.03	−0.51	−3.15
CO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MC	−0.57	−0.77	−0.73	−1.43	0.00	0.84	0.81	−0.62	2.96*	−0.35	−0.25	0.29
CC	0.11	1.22	1.47	3.03*	0.00	−0.43	−1.13	−0.10	−1.18	−0.67	−0.47	−2.36
DC	−0.52	−0.71	−0.67	0.72	0.00	−0.67	1.06	1.36	−0.57	−0.33	−0.23	−0.43
EV	−0.52	0.88	−0.67	0.72	0.00	−0.67	−0.05	−0.57	−0.57	−0.33	−0.23	0.55
RE	−0.30	−0.40	−0.38	−0.75	0.00	−0.38	−0.65	−0.33	2.96*	−0.18	−0.13	0.87
MA	−0.21	−0.28	−0.27	−0.53	0.00	−0.27	2.19*	−0.23	−0.23	−0.13	−0.09	−0.56
OT	−0.25	−0.19	−0.83	−2.28	0.00	0.86	−1.78	−1.44	−0.47	0.83	−0.58	4.84*

*$p < 0.05$

Table 5.6 Adjusted residuals (high-achievement groups)

	ES	MP	ND	AE	CO	MC	CC	DC	EV	RE	MA	OT
ES	1.63	−0.99	0.55	0.81	−0.96	0.76	−0.76	0.65	−0.29	0.90	0.55	−1.51
MP	−1.06	−0.20	−0.97	0.05	−1.14	0.41	2.25*	0.30	0.16	0.54	−0.97	−0.39
ND	−0.81	−0.91	0.73	−1.79	−0.88	−0.67	2.89*	−0.71	−1.13	1.08	−0.75	2.15*
AE	−0.61	−1.59	0.42	0.55	−1.49	0.82	0.88	3.72*	0.35	−0.67	−0.33	−1.58
CO	0.22	−1.07	−0.88	−1.46	11.06*	−0.79	−0.94	−0.84	−0.45	−0.74	−0.88	−1.63
MC	3.50*	0.43	−0.71	−1.70	−0.84	1.06	−1.36	−0.68	1.07	1.19	−0.71	0.53
CC	0.08	−0.25	1.21	2.83*	−1.66	−0.31	−0.65	−1.34	−0.31	−0.17	0.34	−1.04
DC	0.65	1.72	−0.71	−0.14	−0.84	−0.64	0.45	−0.68	0.00	1.19	0.83	−1.32
EV	−0.29	0.34	−1.13	0.93	−0.45	−1.02	0.23	0.00	2.57*	−0.96	0.92	−2.10
RE	−0.64	−0.72	−0.59	−0.49	0.89	1.48	−0.06	−0.56	−0.90	1.63	3.07*	−1.09
MA	−0.77	1.72	−0.71	0.65	0.50	−0.64	−0.46	−0.68	0.00	−0.60	0.83	−0.39
OT	−0.66	2.09*	1.33	−1.90	−1.60	−0.24	−2.08	−1.29	−1.44	−1.15	−1.36	7.14*

$^{*}p < 0.05$

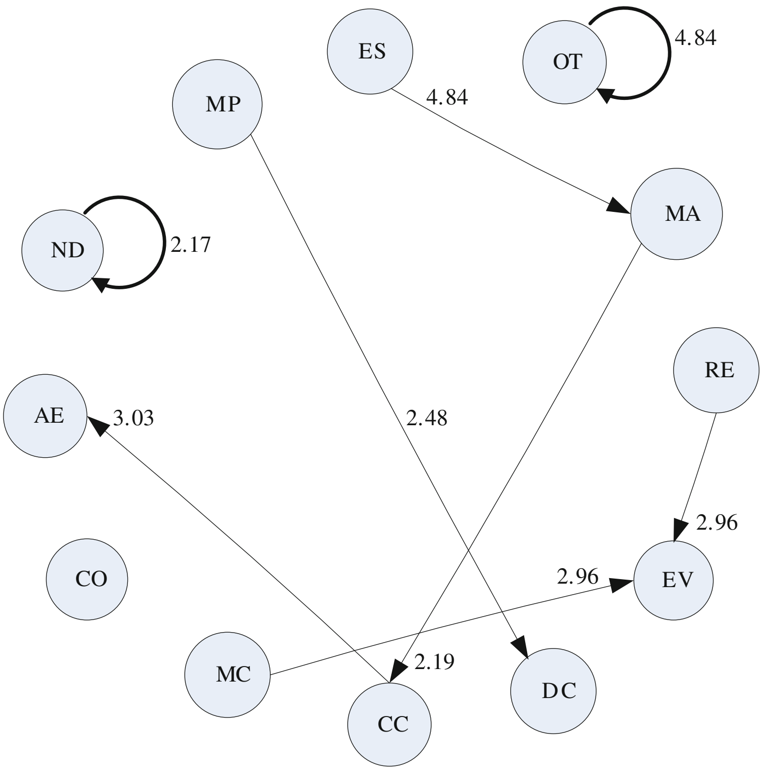

Fig. 5.2 Behavioral transition diagram for low-achievement groups

In addition, the high-achievement groups and low-achievement groups demonstrated different behavioral paths. First, ND → CC occurred in the high-achievement groups, while ND → ND appeared in the low-achievement groups. This revealed that the high-achievement groups could claim (partial) understanding or comprehension failure after negotiating the division of labor, while the low-achievement groups continually negotiated the division of labor. Second, although OT → OT occurred both in the low-achievement groups and high-achievement groups, the high-achievement groups could make plans after an off-topic discussion (OT → MP). This indicated that the high-achievement groups could socially regulate and then return to planning so as to achieve their goals. Third, RE → EV occurred in the low-achievement groups and RE → MA appeared in high-achievement groups. This revealed that the high-achievement groups could make adaptations to goals, or plans, or strategies after reflection, while the low-achievement groups only evaluated the current solutions after reflection.

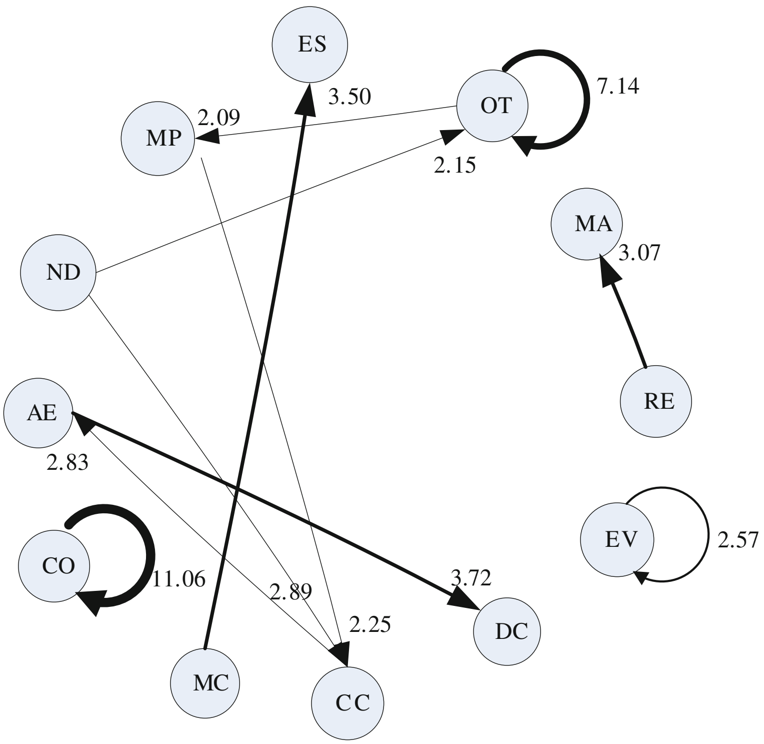

Fig. 5.3 Behavioral transition diagram for high-achievement groups

5.4 Discussion and Conclusion

This study mainly adopted a content analysis method and LSA to identify the behavioral characteristics of socially shared regulation as well as the differences between the high- and low-achievement groups. Socially shared regulation was considered as collective regulation in which group members established shared goals, monitored the collaborative learning processes, and reflected upon and evaluated progress (Järvelä and Järvenoja 2011). Perry and Winne (2013) believed that socially shared regulation is a crucial aspect for productive and successful collaborative learning. The findings indicated that group members could collectively orientate goals, make plans, enact strategies, monitor and control, evaluate and reflect, and adapt meta-cognition during collaborative learning. The results of the sequential analysis revealed that group members could advance new solutions when they claimed partial understanding. They could also detect errors or check plausibility when they advanced new solutions. When they monitored group processed, they could evaluate the current solutions. They could jointly make adaptations after they reflected upon the group's goal and progress. These findings were consistent with a previous report which found that socially shared regulation of learning appeared when group members negotiated shared goals, plans, and strategies (Hadwin et al. 2011). This means group members could collectively regulate their cognition and meta-cognition in the context of CSCL.

This study also examined the behavioral differences between the low- and high-achievement groups. The results indicated more frequent off-topic discussion occurred in the low-achievement groups. Off-topic discussion means that group members do not discuss the concepts to be learned, but they discussed some topics that were not related to the collaborative learning. In addition, no significant behavioral sequences connected off-topic discussion to other on-topic behaviors. This means when learners in the low-achievement groups conducted off-topic discussions, others continued the off-topic discussions. They could not regulate themselves so as to transfer into task-related discussion. This is what the low-achievement groups typically lack during collaborative learning. In addition, the findings revealed that the high-achievement groups could regulate goals, plans, and strategies more frequently than the low-achievement groups. They could also smoothly coordinate conflicts during collaboration. Therefore, they could regulate the aspects that related to the tasks as well as the social aspects. This was consistent with a previous study reported by Malmberg et al. (2015) who found that the high-performing groups could regulate cognitive and motivational aspects as well as social challenges. This finding was also corroborated by Järvelä et al. (2016) who reported that high-achievement groups involved more socially shared regulation activities and that the low-achievement groups lacked socially shared regulation. In short, the analysis of the low- and high-achievement groups' behavioral sequences could help us understand how the groups jointly regulated themselves and what specific aspects may be lacking in the low-achievement groups.

This study has several implications for teachers and developers in the educational field. First, since the low-achievement groups failed in the socially shared regulation of collaborative learning tasks, it is very necessary for teachers to intervene with them in a timely manner. Teachers are recommended to promote participation by extra praise so as to reduce off-topic discussions. Teachers can also introduce several rules to facilitate socially shared regulation when certain circumstances occur. For example, all the group members should collectively make a decision or jointly complete the collaborative learning tasks. Second, this study examined the behavioral patterns of socially shared regulation during collaborative learning. It is strongly recommended that the tools that can automatically analyze user behavior need to be developed for further analysis. These tools can also help to detect off-topic discussion and remind students of this immediately. Third, some specific interaction strategies can promote socially shared regulation. For example, peer assessment or role-playing can facilitate jointly regulation of group work and improve team task coordination (Sipos and Mironescu 2009).

This study was constrained by several limitations. First, the sample was small and only 41 students participated in this study. Future studies will explore the behavioral pattern of socially shared regulation for larger sample sizes. Second, the quality and depth of knowledge building has not been examined in this study. Future studies will detect how students co-construct knowledge during collaborative learning so as to shed light on the relationships between knowledge building and socially shared regulation. Third, the analysis of behavioral patterns was conducted manually in this study, which was time-consuming. Therefore, it is suggested to automatically analyze behavioral patterns and sequences using specific software in future studies.

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Chapter 6
A Socially Shared Regulation Approach to Improving Group Cohesion, Collective Efficacy, and Regulation Skills in CSCL

Abstract Socially shared regulation has emerged as a new research area in collaborative learning. How to promote socially shared regulation in a collaborative learning context is a central issue for researchers. This study sought to develop a CSCL platform with a socially shared regulation mechanism to facilitate group members' socially shared regulation skills. The empirical study was conducted to validate the proposed approach in a natural learning environment. In total, 90 college students participated in this study over 2 months. The results indicated that the proposed socially shared regulation mechanism can significantly improve groups' task cohesion, social cohesion, collective efficacy, and socially shared regulation skills. The implications and limitations of this study are also discussed in detail.

Keywords Socially shared regulation · Group cohesion · Collective efficacy · CSCL

6.1 Introduction

Learning has been shifted from individual learning to collaborative learning in the formal or informal learning environment (Strijbos et al. 2004). Learners can acquire higher levels of learning skills, engage in more complex tasks, and make higher quality decisions in a CSCL context (Hertz-Lazarowitz and Bar-Natan 2002; Janssen et al. 2007). Traditionally, collaborative knowledge building, through productive interactions, has been a major concern in the field of collaborative learning (Bereiter 2002; Resnick et al. 1991). Numerous studies focus on how group members collaboratively construct knowledge in an online learning environment (Lai and Law 2013; Zhang et al. 2009), in a mobile learning environment (Looi et al. 2008), or using social media (Kimmerle et al. 2015). Knowledge building is described as a social process focused on the production and sustained improvement of ideas contributing to a community (Scardamalia and Bereiter 2006). Social interactions among group members can promote co-construction of

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knowledge and contribute to the development of collective knowledge (Scardamalia 2002). However, few studies focus on how group members regulate collaborative learning processes via social interactions in order to construct knowledge.

Although numerous studies reported positive findings about collaborative leaning, there are still some negative aspects about collaborative learning to be found in literature. For example, Straus and McGrath (1994) found students were lacking group cohesiveness during collaborative learning. Hobman et al. (2002) reported that group members had many conflicts in both computer-mediated collaborative learning and face-to-face collaborative learning. In addition, previous studies also found learners fail to collectively regulate the whole groups' goals, plans, strategies, learning processes, and group products (Zimmerman and Schunk 2011). The main reason for this was the regulation of one's own learning is difficult and needs to be supported with specific tools or the correct environment (Hadwin et al. 2010). It is more difficult to jointly regulate group members' learning.

Recently, contemporary studies have started to pay attention to SSRL. This emphasizes the need to be aware of meta-communication and success strategy negotiation (Järvelä et al. 2014; Miller and Hadwin 2015). The main reason for this is that socially shared regulation can facilitate establishing and maintaining a shared understanding of subject matter in order to achieve shared outcomes. As Roschelle and Teasley (1995) reported, collaboration refers to the construct of shared understanding by social interactions with others. Thus, socially shared regulation can serve as a bridge between collaborative learning processes and shared outcomes.

Therefore, the purpose of this study was to propose and validate a new approach to the facilitation of group cohesion, collective efficacy, and socially shared regulation in a CSCL environment. The following section oriented this study according to the findings of the literature review. The methodology of this empirical study is then described. Finally, the results of this study are reported and explained.

6.2 Literature Review

6.2.1 Promoting Socially Shared Regulation in a Computer-Based Environment

Socially shared regulation occurs when group members collaboratively construct knowledge or maintain interdependent processes to achieve joint outcomes (Miller and Hadwin 2015). SSRL involves jointly regulating motivations, emotions, meta-cognition, cognition, and behaviors during collaborative learning (Hadwin and Oshige 2011). During SSRL processes, students need to construct shared task perceptions and establish shared goals as well as plans. When group members have conflicts, they need to negotiate with each other so as to reach a shared understanding of the subject matter. In addition, group members need to collectively monitor the learning process and evaluate group products. In doing so, group members are engaged in shared regulation.

Kempler Rogat and Linnenbrink-Garcia (2011) indicated that socially shared regulation played a crucial role in the collaborative learning process. Therefore, it is very necessary to model socially shared regulation. Winne and Hadwin (2008) proposed a very effective framework for modeling shared regulation. This framework included four phases. The first phase was to establish shared task understanding by analyzing task conditions, standards, and target outcomes. The second phase was to collectively set goals and make plans by negotiating so as to achieve the goals. The third phase was to enact strategies and complete tasks. The last phase was to make adaptations to the task perceptions, goals, plans, and strategies to optimize outcomes.

Numerous studies have demonstrated that technological environments have great potential to help students to be more self-regulated (Aleven et al. 2010; Azevedo and Hadwin 2005; Dabbagh and Kitsantas 2005; Perry and Winne 2006). However, few studies have developed tools to promote socially shared regulation. Many researchers have indicated that elaborately designed collaborative learning tools can provide a rich environment for supporting and promoting knowledge building and coordination (Dillenbourg et al. 2009; Soller et al. 2005). Thus, only a few socially shared regulation tools were proposed and developed in recent years.

There are three types of computer-based environments which can support socially shared regulation. The first type is a script tool that supports macro-script regulation and micro-script regulation (Miller and Hadwin 2015). This tool can structure and sequence socially shared regulation from macro and micro perspectives. Macro-scripts include five key steps, namely preparatory expertise, solo planning, monitoring, group planning, task enactment, and solo reflection. Micro-scripts consist of question prompts and sentence starters that provide learners fine-grained support. The second type are group awareness tools. Group awareness tools have gained attention in the CSCL field as a useful approach to support collaboration. Group awareness tools mainly help learners to be aware of knowledge, behaviors, or the social functioning of their own group and members of other groups (Bodemer and Dehler 2011). Sangin et al. (2011) examined the effectiveness of a knowledge awareness tool on students' collaborative processes and outcomes. Their findings indicated that the knowledge awareness tool prompted students' awareness of knowledge differences and triggered negotiation as well as learning outcomes. The third type was an environment that integrated the awareness tool, shared space, and regulation tool to promote socially shared regulation (Järvelä et al. 2014). The awareness tool can increase learners' awareness of their own groups, and members of other groups, learning processes. A shared space can support group members to collaboratively construct knowledge. In addition, the environment should support the specific phases of regulated learning, including task perception, goal setting, planning, strategic action, and adaptation. Järvelä et al. (2014) developed a Radar tool to promote the awareness of individual self-regulation and the regulation processes of a group. They also developed a group *Ourplanner* and *OurEvaluator* to externalize group planning and learning processes as well as facilitate socially shared regulation.

6.2.2 Task Cohesion, Social Cohesion, and Collective Efficacy

Group cohesion has been recognized as an important factor that influences the collaborative learning process (Mullen and Copper 1994). Group cohesion is characterized as the force binding group members together to achieve goals (González et al. 2003). Previous studies have indicated that group cohesion is positively related to group performance (Mullen and Copper 1994).

Generally speaking, group cohesion includes two aspects: task cohesion and social cohesion. Task cohesion is defined as the degree of group members' commitment to the group task, while social cohesion is conceptualized as the degree of positive interpersonal relationships (Zaccaro and Lowe 1988). Social cohesion also represents the connection one feels to a group (Yamamoto 2011). The meta-analysis results indicate that only task cohesion significantly predicts group performance (Mullen and Copper 1994). Wang and Hwang (2012) also demonstrated that task cohesion positively predicts group performance. Previous studies revealed that groups which were assigned roles outperformed groups without roles in terms of task cohesion (Zheng et al. 2014).

Collective efficacy is conceptualized as a group's shared beliefs in its abilities to achieve group goals (Bandura 1997). Therefore, collective efficacy represents the collective performance ability. Previous studies have revealed that collective efficacy has great impact on group performance (Bandura 1997; Goddard 2001; Gully et al. 2002; Peterson et al. 2000). In addition, collective efficacy also has significant influence on group cohesion (Lee and Farh 2004; Wang and Lin 2007).

Socially shared regulation represents the entire group members collectively regulate their collaborative learning activities. This study hypothesizes that socially shared regulation can promote group task cohesion, social cohesion, and collective efficacy. This study is twofold in its purpose. First, it develops a CSCL platform with a socially shared regulation mechanism. Second, to examine whether group task cohesion, social cohesion, collective efficacy, and socially shared regulation skills can be improved through the socially shared regulation approach. Thus, the five research questions are formulated as follows:

- Can the socially shared regulation approach improve groups' task cohesion?
- Can the socially shared regulation approach improve groups' social cohesion?
- Can the socially shared regulation approach improve groups' collective efficacy?
- Can the socially shared regulation approach improve groups' socially shared regulation skills?
- Can group task cohesion, social cohesion, and collective efficacy predict groups' socially shared regulation skills?

6.3 Development of a CSCL Platform with a Socially Shared Regulation Mechanism

In this study, a CSCL platform with a socially shared regulation mechanism was developed to promote students' shared regulation skills. Overall, the platform can support group members conducting online collaborative learning by task perception, goal setting, making plans, online discussion, monitoring learning progress, as well as evaluating and reflecting. The following section will illustrate how the platform worked with a socially shared regulation mechanism.

Initially, students needed to login to the system after registering. After logging in, students could click the task perception in order to view the current collaborative learning task (Fig. 6.1). Students could then evaluate the current task in terms of difficulty, prior knowledge, expected quality, and required skills (Fig. 6.2). Students could also select prior knowledge linked to the current task and therefore check the prior knowledge of other group members. The group members could set their goals and make plans (Fig. 6.3). After one group member set their goals and made their plans, other group members could revise the goals and plans. Only if all group members agreed with the goals and plans, could they begin to learn. If group members had any questions, they could discuss them online anytime and anywhere (Fig. 6.4). As shown in Fig. 6.4, eight kinds of emotions could be selected during discussion, namely enjoyment, hope, pride, shame, anxiety, anger, hopelessness, and tired. If anyone input negative emotions, prompts would automatically pop-up to remind students to keep with positive emotions. In this way, students could regulate their emotions themselves. Group members could also monitor the learning process through clicking for the latest progress. After group members completed the collaborative learning task, they could upload their group products via our platform. Finally they could conduct self-evaluation via our platform. If they did not achieve

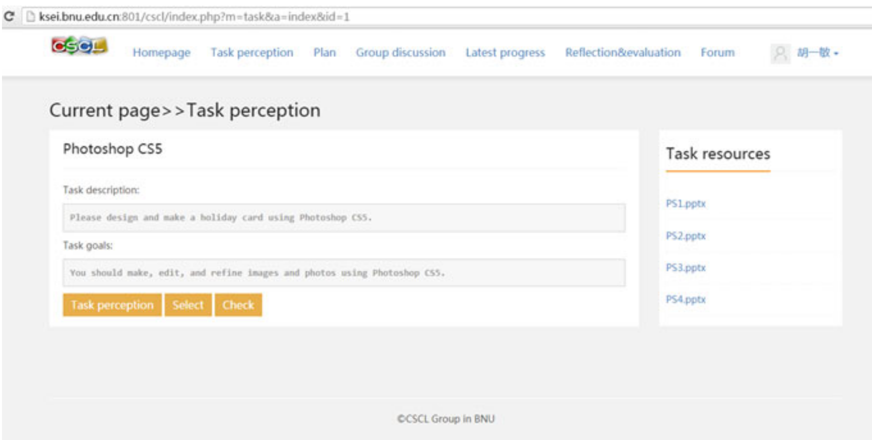

Fig. 6.1 A screen shot of the task description

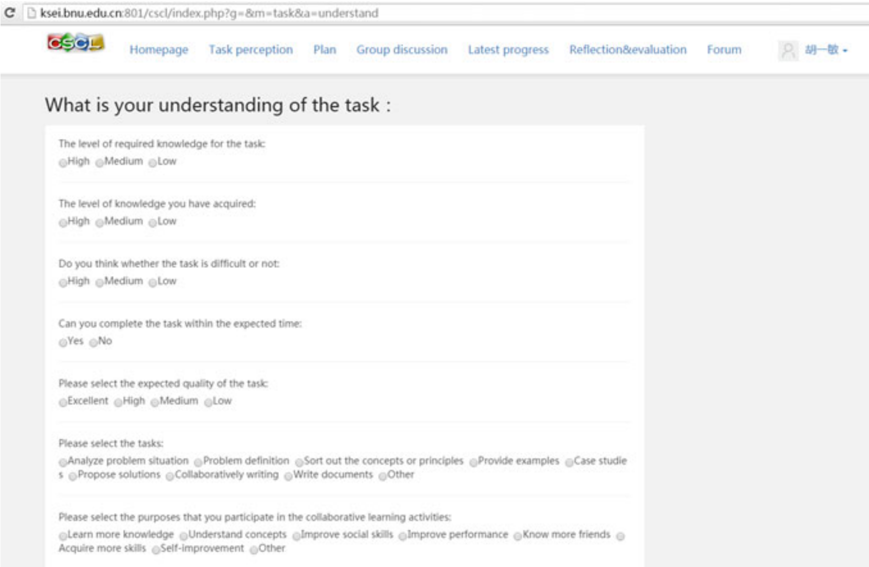

Fig. 6.2 A screen shot of the task perception

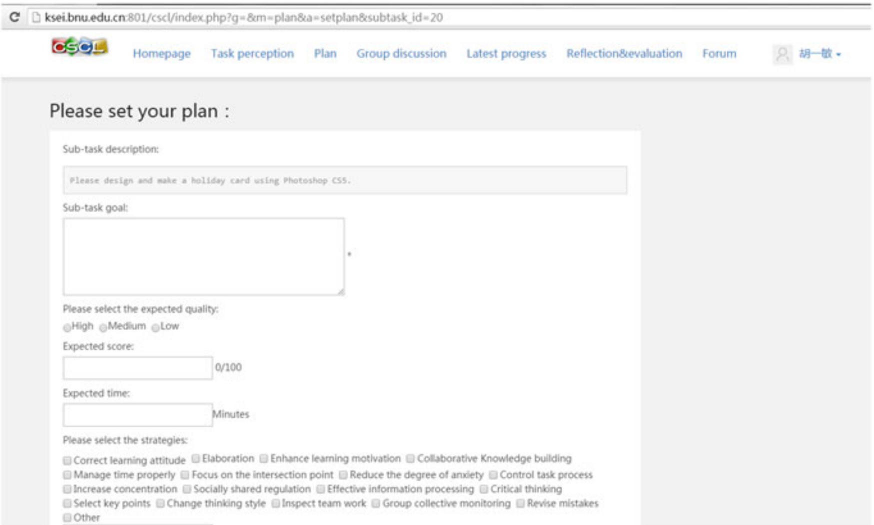

Fig. 6.3 A screen shot of making plans

their goals after self-test, our system would guide students to reset the goals and revise their plans. Sometimes they needed to learn again so as to reach the expected goal. All students could also discuss the topics closely related to the course via our forum (Fig. 6.5).

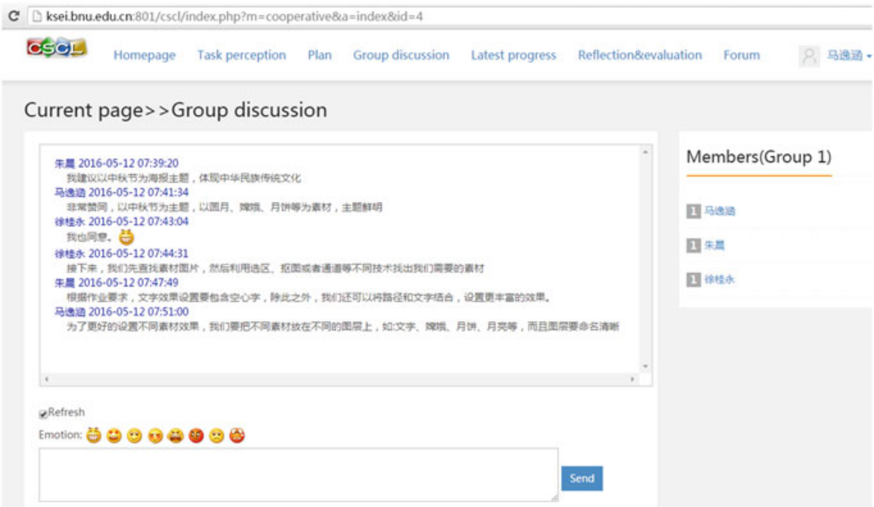

Fig. 6.4 A screen shot of the group discussion

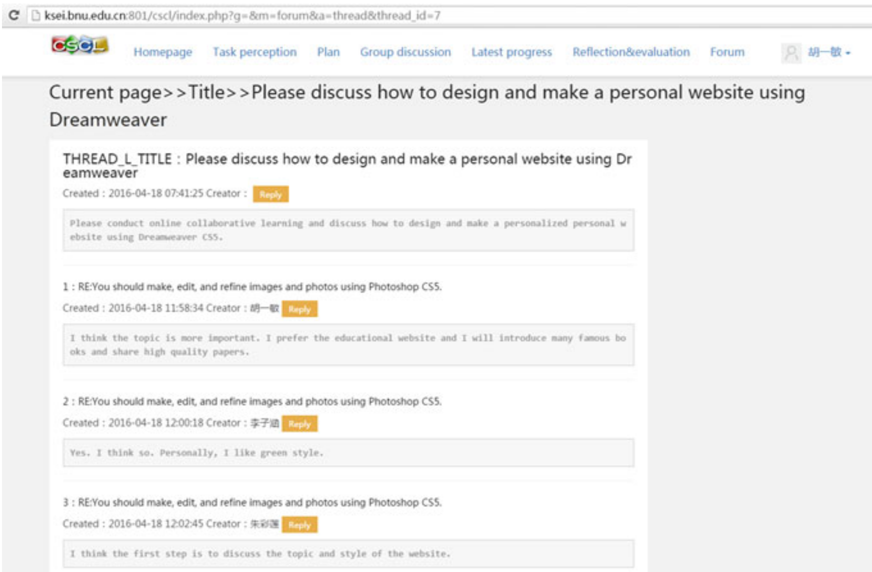

Fig. 6.5 A screen shot of the forum

6.4 Method

In order to examine the influence of a CSCL platform with a socially shared regulation mechanism, a pre-test and post-test quasi-experiment was conducted in one mandatory course for three months. This course was the application of computers worth three academic credits. Several measurement tools were adopted to assess student task cohesion, social cohesion, collective efficacy, and socially shared regulation skills. The following section will describe the research design in detail.

6.4.1 Participants

In total, 90 college students enrolled on the introduction to computers course and voluntarily participated in this study. All of the participants were freshmen in one university in Beijing. About 78 % of them were female. They all majored in law or art. The average age of the participants was 18 years. All of the participants were randomly assigned into 27 groups of 3 or 4 people.

6.4.2 Procedure

In order to examine the effectiveness of the socially shared regulation mechanism, a pre-test and post-test quasi-experiment was conducted in the application of computers course over two months. All of the students needed to collaboratively complete three tasks via the CSCL platform with a socially shared regulation mechanism. The first task was to design a plan about how to set up a wireless network. The second task was to make a poster using Microsoft Word 2013. The third task was to make a courseware using Microsoft Powerpoint 2013. Group members could set their goals, make plans, select and enact strategies, as well as make adaptations through our platform. The final group product could be uploaded via this platform.

Before the first task, the pre-questionnaires about task cohesion, social cohesion, collective efficacy, and socially shared regulation were administered to all participants. This took about 20 min to finish all the items. Subsequently, 27 groups began to conduct online collaborative learning to complete the first task after a teacher's lecture. It took two weeks for groups to finish their first task. Before students completed the second task, the related learning content was taught and shared by teachers and students. All the groups completed the second task within three weeks. When all the groups uploaded their group products, teachers and students evaluated them based on a scoring rubric. The procedure of the third task was the same as that of the second. Thus, two months after the tasks, a post-questionnaire were administered to all of participants. It took about 20 min to finish all the questionnaires.

6.4.3 Instruments

The present study adopted four kinds of questionnaires to measure student task cohesion, social cohesion, collective efficacy, and socially shared regulation skills. The task cohesion questionnaire consisted of seven items with a 5-point Likert scale from (1) "not at all true of me" to (5) "very true of me". Cronbach's α value for the task cohesion questionnaire was 0.841, showing acceptable reliability and internal consistency. The social cohesion questionnaire consisted of eight items with a 5-point Likert scale. Cronbach's α value for the social cohesion questionnaire was 0.816, implying good reliability and internal consistency. The collective efficacy questionnaire consisted of 10 items with a 5-point Likert scale. Cronbach's α value for the collective efficacy questionnaire achieved 0.914, indicating excellent reliability. The socially shared regulation questionnaire consisted of 20 items with a 5-point Likert scale. Cronbach's α value for the socially shared regulation questionnaire reached 0.939, implying excellent reliability and internal consistency. All of these questionnaires were developed by the author. The questionnaires about task cohesion, social cohesion, and collective efficacy were adopted and validated in a previous study (Zheng et al. 2014).

6.5 Results

6.5.1 Analysis of Task Cohesion

Table 6.1 shows the results of the pre-test and post-test for task cohesion. Before the collaborative learning activity, the mean value and standard deviations of the pre-test were 3.57 and 1.23. After the collaborative learning activity facilitated by the socially shared regulation platform, the post-test was administered to all groups. The mean value and standard deviations of the post-test were 4.07 and 0.75. The result demonstrated that there was significant difference between the pre-test and post-test in task cohesion (t = 3.806, $p < 0.01$). This indicated that student task cohesion significantly improved through the socially shared regulation mechanism.

Table 6.1 Descriptive data and t-test for the pre-test and post-test results for task cohesion

Test	N	Mean	Standard deviation	t
Pre-test	90	3.57	1.23	3.806^{**}
Post-test	90	4.07	0.75	

$^{*}p < 0.01$

Table 6.2 Descriptive data and *t*-test of the pre-test and post-test results for social cohesion

Test	N	Mean	Standard deviation	*t*
Pre-test	90	3.71	1.28	3.691**
Post-test	90	4.20	0.65	

*$p < 0.01$

6.5.2 Analysis of Social Cohesion

Table 6.2 shows the descriptive data and *t*-test results for social cohesion. The mean value and standard deviations of the pre-test were 3.71 and 1.28, and 4.20 and 0.65 for the post-test. It was found that there was significant difference between the pre-test and post-test in social cohesion ($t = 3.691$, $p < 0.01$). This result indicated that the groups' social cohesion significantly improved through the socially shared regulation mechanism.

6.5.3 Analysis of Collective Efficacy

In order to examine the collective efficacy of all groups, the pre-test and post-test questionnaires were administered to all students. As shown in Table 6.3, the mean value and standard deviations of the pre-test were 3.63 and 1.20. The mean value and standard deviations of the post-test were 4.08 and 0.66. The results of a paired-sample *t*-test revealed that there was significant difference between the pre-test and post-test in collective efficacy ($t = 3.419$, $p < 0.01$). This finding indicated that the groups' collective efficacy significantly improved after the facilitation of socially shared regulation.

6.5.4 Analysis of Socially Shared Regulation Skills

In this study, the means and standard deviations of the socially shared regulation skills pre-questionnaire were 3.44 and 1.16, and 3.83 and 0.63 for the post-questionnaire (see Table 6.4). The *t*-test results demonstrated there was significant difference between the pre-test and the post-test in socially shared regulation skills ($t = 3.121$, $p < 0.01$), showing that the socially shared regulation approach had a significant impact on students' socially shared regulation skills.

Table 6.3 Descriptive data and *t*-test of the pre-test and post-test results for collective efficacy

Test	N	Mean	Standard deviation	*t*
Pre-test	90	3.63	1.20	3.419**
Post-test	90	4.08	0.66	

*$p < 0.01$

Table 6.4 Descriptive data and *t*-test for the pre-test and post-test results for socially shared regulation skills

Test	N	Mean	Standard deviation	*t*
Pre-test	90	3.44	1.16	3.121**
Post-test	90	3.83	0.63	

*$p < 0.01$

6.5.5 Analysis of the Predictive Power of Task Cohesion, Social Cohesion, and Collective Efficacy

In order to examine whether task cohesion, social cohesion, and collective efficacy can predict socially shared regulation skills, linear regression analysis was performed. The results indicated that only collective efficacy can significantly predict socially shared regulation skills ($\beta = 0.754$, adjusted $R^2 = 0.563$, $t = 10.764$, $p < 0.01$). In other words, students with higher collective efficacy had better socially shared regulation skills.

6.6 Discussion

This study examined whether the socially shared regulation approach can improve the groups' task cohesion, social cohesion, collective efficacy, and socially shared regulation skills. In addition, this study also examined whether a group's cohesion, social cohesion, and collective efficacy can predict socially shared regulation skills.

The results demonstrated that the socially shared regulation approach can significantly improve the groups' task cohesion, social cohesion, collective efficacy, and socially shared regulation skills. The findings can be explained because our platform provided the functionalities, including task perceptions, task standards, task evaluation, and prior knowledge awareness, to promote group members to make a commitment to the group task. In addition, our platform supports group members to collectively set goals, make plans, select strategies, and make adaptations, which can promote social cohesion and collective efficacy. Consequently, the group members' socially shared regulation skills were improved by the facilitation of the socially shared regulation mechanism. These findings were consistent with Järvelä and Hadwin (2013) who proposed that technologies had great potential to facilitate socially shared regulation. These results were also in line with what had been reported by Aleven et al. (2010), namely that technology tools can be used to support students' regulatory skills.

Furthermore, the results demonstrated that only collective efficacy can significantly predict socially shared regulation skills. This means if a group had strong collective efficacy, the group will have good socially shared regulatory skills. This finding was consistent with Bandura (1997) who defined collective efficacy as shared cognition and a belief in the collective capabilities of the group to complete tasks and achieve goals. Socially shared regulation also represented the collective regulatory of goals, plans, strategies, processes, group products, and engagement.

This study has several implications for educators and practitioners. First, in order to equip group members with socially shared regulatory skills, it was necessary to foster the groups' collective efficacy because collective efficacy can promote socially shared regulatory skills. Second, technology tools and scaffolds can indeed promote task cohesion, social cohesion, collective efficacy, and socially shared regulation. Therefore, it is crucial to design a rich collaborative learning environment with a socially shared regulation mechanism in order to promote joint regulatory skills. Third, collaborative knowledge building was only one aspect of collaborative learning. Attention should also be given to socially shared regulation as this represents another crucial aspect of collaborative learning. Teachers and practitioners in collaborative learning should foster socially shared regulation skills for students prior to collaborative learning.

6.7 Conclusion

In summary, the purpose of this study was to contribute to the emerging field of socially shared regulation through the design, development, and validation of a collaborative learning platform with a socially shared regulation mechanism. The results indicated that the socially shared regulation approach can significantly improve groups' task cohesion, social cohesion, collective efficacy, and socially shared regulation skills throughout the 2-month investigation. This study shed light on how to improve socially shared regulation skills in collaborative learning.

However, this study was constrained by several limitations. First, our platform was lacking an adaptive and intelligent scaffold to facilitate socially shared regulation in collaborative learning. Future studies will develop adaptive scaffolds to promote socially shared regulation. Second, currently, socially shared regulation skills are obtained through a self-reported questionnaire. It is very interesting to use trace data or content analysis to analyze how socially shared regulation skills evolve as well as the relationships between socially shared regulation skills and group performance. Third, current collaborative learning tasks mainly focus on one subject domain. Future studies will examine the effectiveness of a socially shared regulation mechanism in other learning domains. Finally, analysis of knowledge building and group performance has not been conducted in this study. Future studies will explore the relationships among group performance, socially shared regulation, group cohesion, and collective efficacy.

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Part III
Case Studies in CSCL: Facilitation and Reflection

Chapter 7
Promoting Productive Collaborative Learning Using Concept Maps: A Case Study

Abstract This chapter outlines how concept mapping and collaborative learning were integrated and implemented within an information communication technology course for foreigner graduates. This approach makes use of *CmapTools* as a shared space for facilitating productive collaborative learning in nature learning settings. The result indicated that group members can use *CmapTools* to co-construct knowledge. However, most students only shared and compared information. They seldom tested and modified ideas during collaborative learning. Most groups constructed high-quality concept maps. Only one group had the highest quality of socially shared regulation. The implications for teachers and practitioners are also discussed. This chapter concludes with ideas about future studies on collaborative concept mapping.

Keywords Collaborative learning · Concept map · *CmapTools*

7.1 Introduction

The rapid development of information technology, knowledge explosion, and globalization has dramatically influenced our society (Friedman 2007), producing a new set of social paradigms. Our society has shifted from industrial to post-industrial to information, in which power mainly depends on the possession of ideation resources and information (Correia and Infante-Malachias 2010). The information age also poses many new challenges for us. One of the challenges is to modify the education system in order to meet the demands and equip citizens with lifelong learning skills since the most important skill in the information age is to learn how to learn (Georghiades 2004). Beyond transmitting disciplinary knowledge, education in the information age also requires the abilities for lifelong learning, creative thinking, teamwork, and collaborative knowledge building (Burnard 2006; Pintrich 2004; Sawyer 2006).

In order to respond to the demands of the information age, educators and practitioners have conducted face-to-face and online collaborative learning to foster

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learners' critical thinking skills and lifelong learning abilities for more than two decades. Collaborative learning is the practice of meaning-making and social interaction in a joint activity to achieve a shared understanding (Stahl et al. 2006). Collaborative learning is also a coordinated activity that is the result of continually constructing and maintain a shared conception of a problem (Roschelle and Teasley 1995). In order to scaffold collaborative learning, many methods or technologies provide affordance for productive collaborative learning. A concept map is one very effective method to promote productive and successful collaborative learning.

In this study, we directed our attention to collaborative concept mapping to promote productive collaborative learning using *CmapTools* in a natural learning setting. The purpose of this study was to understand how learners collaboratively construct concept maps online. Thus, the research questions are formulated as follows:

1. How do group members interact with each other during collaboratively constructing concept maps?
2. What characteristics do high-quality concept maps have?
3. What characteristics does a high performing group demonstrate during collaborative learning?

7.2 Literature Review

7.2.1 Collaborative Learning

Collaborative learning is a planned methodology for use in groups to develop learning skills, personal knowledge, and social relationships (Torres et al. 2010). Collaborative learning is based on the idea that learners influence each other when they share knowledge and negotiate its meaning (Baker et al. 1999). There have been many efforts reported in the literature about the advantages of collaborative learning. For example, collaborative learning provides good opportunities to share and experience multiple perspectives from different backgrounds as well as develop critical thinking skills (Hakkarainen et al. 2002; Stacey 1999).

Koschmann (2002) proposed that CSCL is a field of study centrally concerned with meaning and the practices of meaning-making in the context of joint activity, and the ways in which these practices are mediated through designed artifacts. With the development of advanced technologies, researchers have sought to adopt emerging technologies to support collaborative learning. For example, Wu et al. (2013) developed a mind map based collaborative learning approach to support creative learning activities and enhance learning performance. Sung and Hwang (2013) developed a collaborative game based learning environment by playing games to improve students' learning performance in science courses. Sun and Looi (2013) designed a web-based science learning environment to support collaborative inquiry-based learning.

Information technology can potentially serve as a computational and communication media creating a collaborative learning environment and facilitating successful collaborative learning. Suthers (2005) proposed that technology can also be viewed as a resource to draw upon to facilitate collaborative learning processes. To sum up, a variety of technologies can be used to promote collaborative learning in terms of social interactions, sharing information, and knowledge building.

7.2.2 Concept Maps

A concept map is defined as a graphical tool for representing knowledge. A concept map consists of concepts and their relationships (Novak and Cañas 2006). Concepts are defined as "perceived regularities in events or objects, or records of events or objects, designated by a label" (Novak 1998, p. 21). As a unique feature of concept maps, propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit (Novak and Gowin 1984). Another feature of concept maps is cross-links that show how concepts are connected to each other (Novak and Cañas 2006).

There are different types of concept maps, such as chain or sequential maps, hierarchical maps, and cyclical concept maps. Chain maps are used for a sequence of events or a timeline. Hierarchical maps are typically tree structures, in which the more general concepts are at the top of the map and the specific concepts are at the bottom. Cyclical concept maps are used for representing a self-contained system with a closed loop (Ng and Hanewald 2010). Concept maps are based on Ausubel's theory of meaningful learning (Novak 1998). Meaningful learning centers on building one's cognitive structure by assimilating new concepts into prior conceptual structures (Ausubel 1968). Therefore, concept maps can serve as a bridge between new concepts and prior knowledge.

Concept maps can be used for demonstrating and communicating ideas in brainstorming or presentation activities. Students can use concept maps to organize their understanding of a subject matter. Teachers can use concept maps to present learning content and diagnose learners' understanding. Concept maps can also be used for generating ideas when different concepts are linked together. An obvious advantage of concept maps is that the learner can sharpen their thinking and reflect concepts and their relationships, which can help foster the development of life-long learning skills and critical thinking skills (Ng and Hanewald 2010). Previous studies also reported that concept maps had a positive effect on knowledge gains and attitude (Horton et al. 1993). In recent years, concept maps have been widely used in different fields for representing and visualizing knowledge. Nesbit and Adesope (2006) found that use of concept maps has grown rapidly as a tool for supporting teaching and learning. They also reported that the use of concept maps produced increased retention and transfer of knowledge as well as positive attitudes toward learning when compared with control conditions. Bahr and Dansereau

(2001) revealed that the use of a concept map can lower anxiety and frustration while increasing motivation.

A good concept map is based on a solid theory of learning and knowledge (Cañas and Novak 2008). Cañas et al. (2015) proposed that a good concept map should have good graphical structure, accurate semantics, and be of high quality. Therefore, when we construct a concept map we should take into account good hierarchical structure, concise semantic relationships, and excellent concept map quality.

7.2.3 Collaborative Learning Using Concept Maps

Educators are now seeking new methods or technologies to respond to the demand for personalized education and knowledge creation. Concept mapping is a powerful technique that can facilitate knowledge creation in the 21st century (Torres et al. 2010). Currently, concept mapping has been integrated into collaborative learning activities to facilitate productive collaborative learning and artifacts. Thus, collaborative concept mapping has been an interesting method that responds to educational demands.

The effectiveness of collaborative concept mapping has been examined in previous studies. Cañas et al. (2003a, b) believed that the combined use of a concept map and collaborative learning may synergistically amplify the benefits by facilitating knowledge building and active engagement. Researchers have reported that collaborative concept mapping can successfully sustain critical thinking and meaningful knowledge building (Stoyanova and Kommers 2002). Engelmann and Hesse (2010) conducted an empirical study giving 20 triads access to concept maps and 20 triads no access to concept maps to compare their group performance in problem-solving tasks. They found that the triads with concept maps acquired more knowledge and solved problems faster and more correctly than triads with no access to concept maps. Collaborative learning with concept maps was more effective than other activities with non-map materials. However, no effect of studying pre-constructed concept maps was significantly detected in a collaborative learning context (Adesope and Nesbit 2010).

7.3 CmapTools

There is lots of software that enables drawing a concept map collaboratively. For example, *Conceptshare* (http://www.conceptshare.com) is a collaborative learning environment with annotation tools which enable the creation of concept maps. *Thinkature* (http://thinkature.com) is another web-based visual workspace for collaborative concept mapping. However, the most popular and widely used concept map tool is *CmapTools*.

CmapTools is a free web-based concept mapping tool (http://cmap.ihmc.us). *CmapTools* was developed by the Institute of Human and Machine Cognition to enable users to collaboratively construct concept maps (Cañas et al. 2003a, b). *CmapTools* is a tool that can support synchronous and asynchronous collaboration,

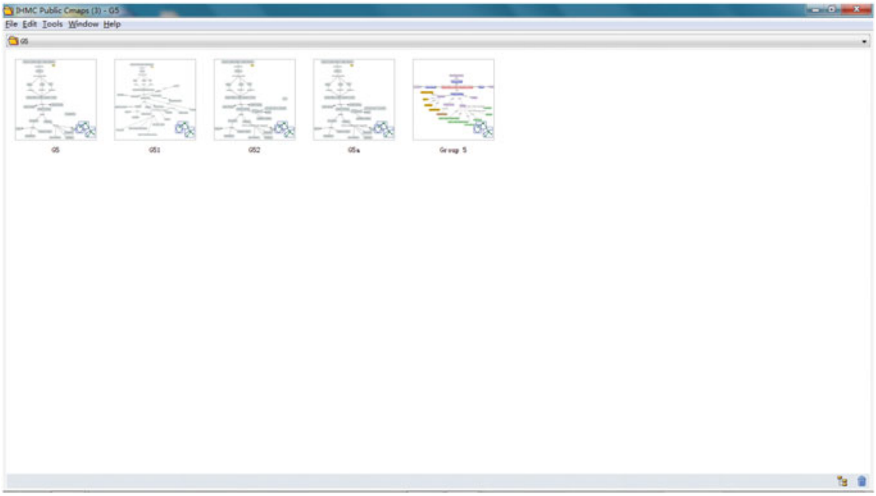

Fig. 7.1 Concept maps constructed using *CmapTools*

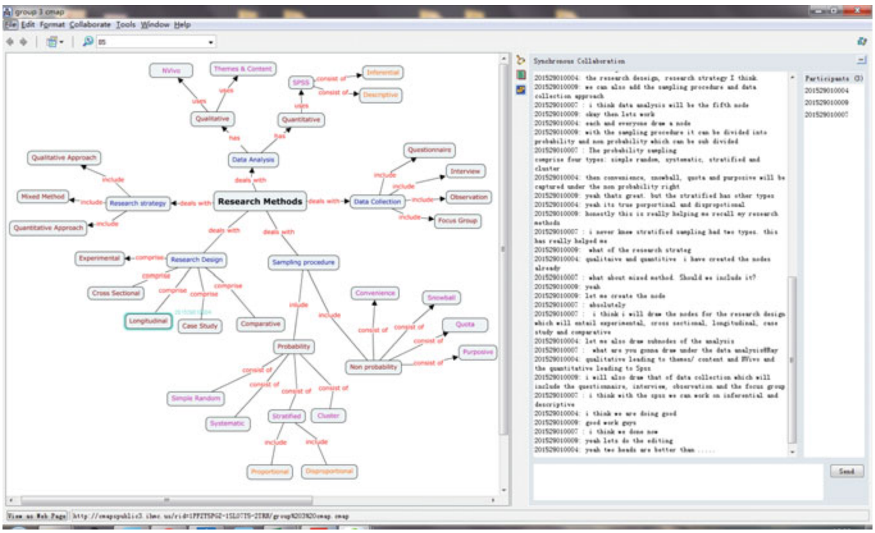

Fig. 7.2 Synchronous collaboration using *CmapTools*

involving two or more learners, in co-construct concept maps. Figure 7.1 shows the concept maps constructed using *CmapTools*. Figure 7.2 shows the synchronous collaboration via *CmapTools*. Users can browse and edit concept maps produced by other learners, at the same time they can discuss online, enabling them to revise concept maps.

7.4 Methodology

7.4.1 Participants

Participants in this study included 19 foreign studen from Tanzania, Ghana, Eritrea, Zambia, Malawi, German, Korea, India, and China. Among the 19 students, 47 % of them were female and 53 % were male. Most of them were masters students and only two of them were PhD students. Four students majored in higher education and thirteen majored in comparative education. The other two students majored in educational technology. All of the students enrolled on the course entitled "ICT in higher education and student affairs" worth two academic credits. This course covers the applications of IT in higher education and student affairs. This course offers a broader scope than ICT in higher education as well as offering hands-on experience with technology tools to enhance productivity and creativity for student affairs, at the same time allowing students to study deeper into topics of interest.

7.4.2 Procedure

This course was taught in a blended learning mode, namely using face-to-face instruction and online learning. Every week students went to classrooms for face-to-face instruction or discussions for 2 h. After that they learned using the Schoology platform (https://www.schoology.com/) anytime they wanted and in any place. This course included two individual assignments and two group assignments. One of the assignments was to collaboratively draw concept maps based on selected topics. All groups could select the topics that they are interested in. The purpose of this assignment was to help students stay organized with regards to time, ideas, and resources allowing them to decide when they work independently and in groups. Thus, *CmapTools* was the most appropriate tool to help students organize compared with other tools.

Before the group assignments, training about how to use *CmapTools* was conducted in the classroom. A research assistant demonstrated the steps of using

CmapTools, especially how to collaborate online. Subsequently, 19 students were randomly assigned into 5 groups of 3 or 4 people. After that, each group discussed the topics, schedules, role assignments, and how to complete this task using *CmapTools*. Each group took about three weeks to complete this group assignment. The final group product was a concept map closely related to the selected topic. After every group has completed the tasks, they demonstrated how they collaboratively drew concept maps as well as showing their group products in the classroom. Their classmates conducted peer assessment to evaluate group performance based on the scoring rubric.

7.4.3 Data Collection and Analysis

The data source in this study included discussion transcripts and concept maps. The discussion transcripts of all groups were automatically logged by *CmapTools*. The concept maps were also saved using *CmapTools*. This study adopted a content analysis method to analyze the patterns of knowledge building, knowledge advancement, and the quality of concept maps. The group performance was scored based on peer assessment results.

Table 7.1 shows the coding scheme for the interaction pattern. The coding scheme was developed by Gunawardena et al. (1997). Table 7.2 shows the scoring rubric for the concept map, which was adapted from Cañas et al. (2008). Table 7.3 shows the rubric for group performance, which was revised based on the Texas Education Agency (2006). Two raters independently coded all of the discussion transcripts based on the coding scheme. They also evaluated all the concept maps based on the scoring rubrics. The inter-rater reliability was calculated via the Kappa coefficient. The results demonstrated that the Kappa coefficient for knowledge building was 0.85 with a coefficient of 0.88 for the concept maps, indicating good reliability. Two raters discussed and solved all discrepancies.

Table 7.1 The coding scheme of the interaction pattern

Code	Examples
Sharing or comparing information	What's the differences between the qualitative method and quantitative method?
Discovery and exploration of dissonance	I think this node was put in the wrong place
Negotiation of meaning	Let's make a little change about the topic
Testing and modification of ideas	We can probably modify some of them
Agreement statements	Perfect explanation
Off-topic discussion	Will you go shopping this weekend?

Table 7.2 Semantic scoring rubric for concept maps

Criterion	Description	Scores
Concept relevance and completeness	The map contains few concepts or most concepts are irrelevant, redundant, or not well-defined	1
	One half or more of the map's concepts are relevant and well-defined, but many important concepts are missing	2
	Most concepts are relevant and well-defined, but some important concepts are missing	3
	All concepts are relevant and well-defined; no important concepts are missing	4
Propositions as "semantic units"	Very few propositions are well constructed	1
	Some propositions are well constructed	2
	All or most all propositions are well constructed	3
Erroneous propositions	The map contains more than 2 erroneous propositions	1
	The map contains 1-2 erroneous propositions	2
	The map contains no erroneous propositions	3
Quantity and quality of cross-links	The map contains cross-links, but they are all erroneous (false)	1
	The map contains no cross-links	2
	The map contains 1–2 correct, relevant, and adequate cross-links with physically separate links	3
	The map contains more than 2 correct, relevant, and adequate cross-links with physically separate links	4
	The map contains all important, correct, and relevant cross-links with physically separate links	5

Table 7.3 The scoring rubric of group performance

Criteria	Weight	Explanations
Collaboration	25	• Do a full share of work or more • Assign a clearly defined role; group members perform roles effectively • Always consider all views and help the group to reach fair decision • Never argue with teammates • Group tries to solve its problems by itself
Organization	20	• Take initiative in helping the group get organized and setting times and places to meet • Product is extremely well organized • Have realistic and measurable goals • Highly productive in accomplishing assignment
Research	20	• Collect and contribute accurate content • Provide enough evidence to validate the ideas • Goes above and beyond to research information • Communicate and share all information with the group • Co-construct their own ideas and knowledge

(continued)

Table 7.3 (continued)

Criteria	Weight	Explanations
Member responsibility	20	• Provides many ideas for the assignment • Clearly communicates desires, ideas, personal needs, and feelings • Each team member is treated with respect and is encouraged • Hands in all assignments on time
Presentation	15	• Presentation is clever and original • Engaging; captures interest of audience • Appropriate variety of visual aids • Each presenter speaks clearly and loudly; good eye contact; appropriate body language • Members contribute equally to the presentation

7.5 Results

7.5.1 Analysis of Interaction Pattern

Table 7.4 shows the percentages of the interaction pattern for each group. The main categories include sharing or comparing information, discovery and exploration of dissonance, negotiation of meaning, testing and modification of ideas, and agreement statements. Overall, most conversation focused on sharing and comparing information, followed by off-topic discussion and negotiation of meaning. Testing and modification of ideas accounted the least. The results also indicated that Group 3 had the least off-topic discussions and Group 1 achieved the highest proportion of off-topic discussions.

Table 7.4 The percentages of the interaction pattern

Criterion	All groups (%)	Group 1 (%)	Group 2 (%)	Group 3 (%)	Group 4 (%)	Group 5 (%)
Sharing or comparing information	38.29	30.59	41.78	20.90	33.98	71.43
Discovery and exploration of dissonance	3.90	5.88	3.13	4.48	5.83	0.00
Negotiation of meaning	21.02	17.65	21.41	34.33	16.50	10.71
Testing and modification of ideas	2.10	1.18	2.09	0.00	4.85	0.00
Agreement statements	11.71	9.41	8.09	31.34	15.53	7.14
Off-topic discussion	22.97	35.29	23.50	8.96	23.30	10.71

7.5.2 Analysis of Socially Shared Regulation

In order to examine how group members interact with each other and collectively regulate during collaborative learning processes, the overall quality of the socially shared regulation of five groups was analyzed. It was found that Group 4 had the highest quality in two ways. First, there were frequent instances of goal setting, planning, monitoring, and evaluation. The most notable aspect was their frequent attempts to jointly regulate so as to set a common goal and achieved shared understanding. For example, one group member selected one topic and asked others whether they agreed with this topic.

Member A: Hello guys. What are the topics that we are supposed to work with?
Member B: Media that facilitate teaching and learning.
Member C: I don't agree with you. Personally, I prefer student affairs.
Member B: More specifically, we can also select social media.
Member A: Oh, which one is better?
Member C: I think the student affair is nice.
Member A: We can give room to others to propose, then we can come to an agreement on one topic. Member D, are you there?
Member D: I am online now. I agree with you guys.
Member A: Which one?
Member D: I mean student affair.
Member A: Oh. But I get another one. What about ICT integration in higher education?
Member B: Sounds good.
Member D: Yes. It is very interesting.
Member C: Yeah, I agree with you.
Member A: Thus, all of us agree with this topic. Let's work out it.

Second, their synergy among the regulatory processes had a strong influence on co-constructing knowledge. They adopted high-quality social regulation to maintain productivity and facilitate knowledge building. They collaboratively set goals and made plans to guide their learning. They also kept track of their progress to avoid pitfalls. For example, one group member was not satisfied with time management.

Member A: Hello guys. How is going?
Member B: Not very smooth.
Member C: The main reason is that we don't have a schedule. I think it is necessary to make a schedule.
Member D: I agree with you. Let's make a schedule now.
Member A: Next, we can act based on this schedule.
Member C: Exactly, then we still need to monitor our process so as to complete the task on time.
Member D: Sure. Now we can focus on our topic and think about how to integrate ICT in higher education.

Table 7.5 The evaluation results of concept maps

Criterion	Group 1	Group 2	Group 3	Group 4	Group 5
Concept relevance and completeness	2	3	4	3	3
Propositions as "semantic units"	3	2	3	3	3
Erroneous propositions	1	3	3	2	3
Quantity and quality of cross-links	4	5	5	5	4
Total	10	13	15	13	13

7.5.3 Analysis of the Quality of Concept Maps

Based on the aforementioned rubric for concept maps, five groups' concept maps were evaluated by two raters. Table 7.5 shows the evaluation results of five groups' concept maps. It was found that Group 3 achieved the highest score and Group 1 the lowest. Figures 7.3 and 7.4 show the concept maps constructed by Group 3 and Group 4, respectively.

7.5.4 Analysis of Group Performance

Group performance was evaluated by peers based on the abovementioned rubric. When each group presented the final product and the entire collaborative learning process, other groups assessed group performance in terms of collaboration, organization, research, member responsibility, and presentation. The final score was

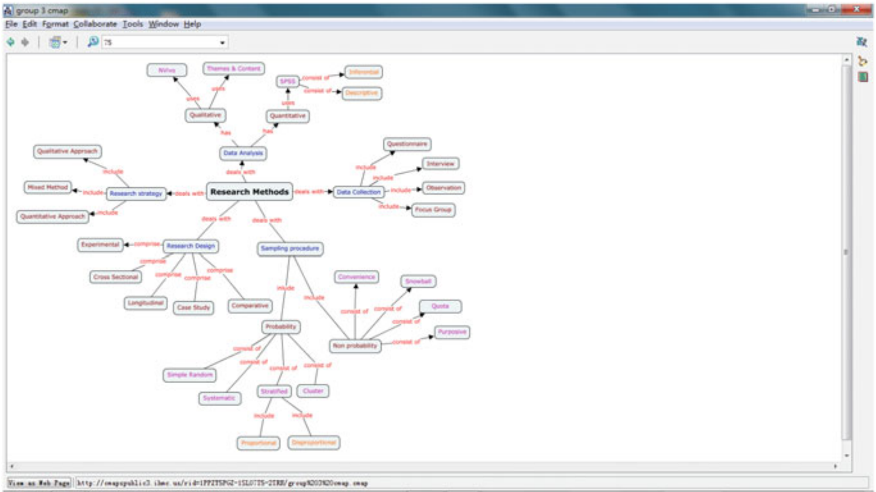

Fig. 7.3 The concept map constructed by Group 3

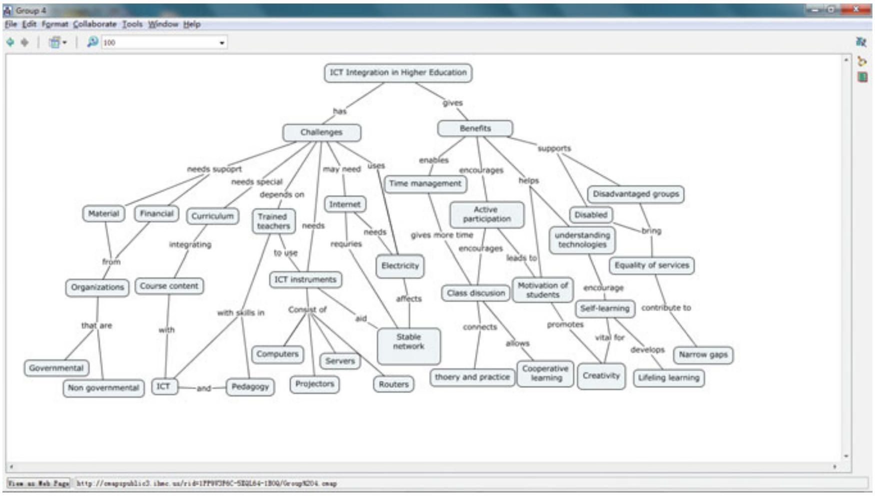

Fig. 7.4 The concept map constructed by Group 4

Table 7.6 The results of group performance

	Group 1	Group 2	Group 3	Group 4	Group 5
Cooperation	22.43	22.14	21.80	23.00	21.81
Organization	18.00	17.57	18.33	18.36	17.56
Research	18.11	18.21	17.80	18.82	17.44
Member responsibility	17.64	17.36	17.53	17.82	17.91
Presentation	13.25	13.00	12.93	13.50	13.44
Total score	89.43	88.29	88.40	91.50	88.16

equal to the average score of the five aspects. Table 7.6 shows the results of group performance. It was found that Group 4 achieved the highest score and Group 5 the lowest.

7.6 Discussion

Collaborative knowledge building is a central issue in the field of collaborative learning. Knowledge building can result in the creation or modification of public knowledge, which leads to personal learning (Scardamalia 2003). Knowledge building is a social process focused on sustained improvement of ideas (Scardamalia and Bereiter 2006). Understanding collaborative learning requires making sense of conversations and examining the patterns of social interaction and knowledge building (Hmelo-Silver 2003). This study divided social interaction patterns into five phases: sharing or comparing information, discovery and exploration of dissonance, negotiation of meaning, testing and modification of ideas, and agreement statements. The results indicated that most conversations focused on sharing or comparing information as well as negotiating meaning. Testing and modification of ideas accounted for the least. This finding revealed that learners only shared information and negotiated meaning during collaborative learning. Creating and modification of ideas still remained lacking.

The *CmapTools* provided a shared space for collaborative learning in both designing and completing tasks. Previous studies also indicated that shared workspaces can reduce coordination and regulation since shared workspaces support work awareness and the mutual understanding of peers (Gutwin and Greenberg 2002). Shared workspace can also reduce verbal negotiation because many user actions are immediately visible to all group members (Hron et al. 2007). The *CmapTools* we used for this study allowed collaborative drawing and editing of concept maps as well as facilitating knowledge building among group members. In order to investigate the effectiveness of *CmapTools*, we differentiated several different knowledge building patterns. We also analyzed the quality of concept maps and group performance based on the rubrics. The results indicated that the quality of the concept maps differed from each group. Good concept maps have a high quality of both structure and content (Cañas et al. 2015). In terms of the structure of concept maps, it is better to put the most general concepts at the top and the specific concepts at the lower level. Overall, the concept maps should have hierarchical organization and focus on the central idea. The findings of this study indicated that Group 3 got the highest score in terms of concept mapping since their concept map had the highest quality of structure and content.

Group performance is a central issue in collaborative learning. Many researchers adopted different criteria to evaluate group performance, such as the learning achievements of all group members, group products, knowledge gains, or knowledge transfer. Previous studies reported that group performance was influenced by several different factors, such as assigned roles (Strijbos et al. 2007), knowledge awareness (Sangin et al. 2011), advanced technologies (Blasco-Arcas et al. 2013; Wu et al. 2013), and transactive memory (Michinov and Michinov 2009). In the present study, group performance was evaluated based on the final group product and the collaborative learning processes. The score of group performance was obtained by peer assessment and teacher evaluation. In order to improve group performance, it is necessary to refine the collaborative learning process and improve group products.

The practical implications of this study shed light on the design and implementation of collaborative learning. First, the task of collaborative learning needs to be designed elaborately. Second, the environment of collaborative learning should provide a shared space to allow group members to be easily aware of each other actions, ideas, and emotions. The shared space can facilitate the process of knowledge building and understanding of subject matter. Finally, the outcome of collaborative learning needs to be evaluated from different perspectives, including knowledge gains, social skills, cooperation skills, group products, collaborative learning processes, attitudes toward learning, and emotions related to learning. If the attitudes and emotions of learners change from passive to positive after collaborative learning, then the true value of collaborative learning becomes apparent.

7.7 Conclusion

This study examined the effectiveness of collaborative concept mapping using *CmapTools*. Overall, group members can use *CmapTools* to collaboratively draw concept maps and construct knowledge. However, most learners only shared and compared information. They seldom tested and modified ideas. The qualities of concept maps for most groups were very high because of good structure and content.

This study has several limitations. First, this study had no control group to compare the effectiveness of collaborative concept mapping. Future studies will examine the differences in social interaction patterns, the quality of concept maps, as well as group performance between the experimental group and control group. Second, the sample size of the present study was small. Therefore, caution should be made when generalizing the results. Future studies will expand the sample size to validate the effectiveness of collaborative concept mapping. Finally, the duration of this study was also short; three weeks was not enough for learners to co-construct knowledge deeply. Future studies will conduct longitudinal studies to investigate the influence of shared space on social interaction, knowledge building, and group performance.

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Chapter 8
Scripted Collaborative Learning Using the Modified Jigsaw Method: An Empirical Study

Abstract Free collaboration cannot necessarily result in successful collaborative learning. This study explored scripted collaborative learning in the shared space facilitated by *Cmaptools*. The purpose of this study was to examine the effectiveness of the modified jigsaw method. In contrast with the traditional jigsaw method, the modified jigsaw can establish common ground and shared cognition. An experiment was conducted in the lab to evaluate the effects of the modified jigsaw. The experimental results indicated that the modified jigsaw was more effective than the traditional jigsaw in terms of enhancing group performance, task cohesion, and collective efficacy. The implications for practice and future studies are also discussed in detail.

Keywords Collaborative learning · Jigsaw · Group performance · Task cohesion · Collective efficacy

8.1 Introduction

Collaborative learning has been paid increasingly attention in recent years. The effectiveness of collaborative learning has been well documented in the literature (Fischer et al. 2007). However, the effectiveness of collaborative learning depends on many factors, including group size, age, gender, heterogeneity, prior knowledge, tasks features, and so on (Dillenbourg 2002). It is very obvious that both the external conditions and internal conditions have great impacts on the effectiveness of collaborative learning. However, the internal conditions are more important than external conditions. Therefore, Dillenbourg et al. (1995) migrated from external conditions to internal conditions and focused on internal factors as well as the actual collaborative learning processes. This means the social interactions among group members are the major concern in collaborative learning. As Johnson and Johnson (1987) noted, successful collaborative learning requires group members to interact with each other socially. These interactions among group members are very complex. A previous study reported that free collaboration cannot necessarily lead to productive

L. Zheng, *Knowledge Building and Regulation in Computer-Supported Collaborative Learning*, Perspectives on Rethinking and Reforming Education,
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collaborative learning (Dillenbourg et al. 2009). Therefore, social interactions need to be structured in order to achieve successful collaborative learning outcomes.

Scripted collaborative learning is an effective method for structuring collaborative learning. Scripts are a set of instructions that specialize group formation, distribution of resources, role assignment, and sequences of activities (Fischer et al. 2007). A jigsaw is one well-known scripted method for collaborative learning. The jigsaw method structures collaborative learning into expert groups and jigsaw groups (Balestrini et al. 2014). First, a collaborative learning task is broken up into different sub-tasks. Second, the expert groups are assigned one sub-task and work together to complete it. Third, students who are assigned different sub-tasks form the jigsaw groups and share every sub-task (Aronson and Patnoe 1997). Thus, the jigsaw method promotes the interdependence of group members and cognitive elaboration by considering different perspectives (Hinze et al. 2002).

However, previous studies revealed that the jigsaw method reduced learners' common ground and hindered knowledge building among group members (Deiglmayr and Schalk 2015). Therefore, this study proposed the modified jigsaw method in order to establish common ground and help learners to gain more knowledge. The main difference between the modified jigsaw method and the traditional jigsaw lies in the first phase. With respect to the modified jigsaw, all of the group members need to complete all of the sub-tasks in the first phase. By comparison, group members only need to complete one sub-task in the traditional jigsaw. Therefore, the purpose of the modified jigsaw is to improve knowledge gains and establish common ground among group members.

In this study, we adopted the modified jigsaw script to conduct online collaborative learning. The purpose of this study was twofold. First, it aimed to explore the feasibility of the modified jigsaw method. Second, it examined the effectiveness of the modified jigsaw method in terms of group performance, task cohesion, and collective efficacy. The research questions are addressed as follows.

1. Is a modified jigsaw method more effective than the traditional jigsaw method in terms of improving group performance?
2. Is a modified jigsaw method more effective than the traditional jigsaw method in terms of promoting task cohesion?
3. Is a modified jigsaw method more effective than the traditional jigsaw method in terms of improving collective efficacy?

8.2 Literature Review

8.2.1 Scripted Collaborative Learning

Collaborative learning is a learner-centered approach that enable students to co-construct knowledge, skills, and attitudes by social interactions. Collaborative learning includes five basic elements, namely positive interdependence, individual accountability, social skills, group processing, and social interactions (Johnson and Johnson 1987). In order to achieve successful and productive collaborative learning, these five factors are essential and crucial. Previous studies reported that collaborative learning can improve information retention, higher order thinking skills, interpersonal skills, and self-confidence (Lindquist 1997; Lorenzen 2003; Millis and Cottell 1997).

There are two types of collaboration activity. One is free collaboration, the other is scripted collaboration. In terms of free collaboration, the collaborative learning activity is unstructured. However, some researchers posited that free collaboration cannot engage all group members in collaborative learning (Demetriadis et al. 2009; Liu and Tsai 2008) and that it can lead to low phases of critical thinking (Aviv et al. 2003). Scripted collaboration is structured but may cause inflexibility and increase cognitive load (Dillenbourg and Jermann 2007). This study focused on scripted collaboration so as to make collaborative learning processes more structured.

A collaboration script is a set of instructions that indicate how group members interact and collaborate with each other (O'Donnell and Dansereau 1992). A script also specializes the mode of collaboration. Dillenbourg (2002) indicated that most scripts include a linear sequence of phases and every phase is specialized to the task, group, mode, and timing requirements. There are different types of scripts, including induced scripts, instructed scripts, trained scripts, prompted scripts, and follow-me scripts (Dillenbourg 2002). Aronson et al. (1978) posited that the best-known collaboration script is the jigsaw. The following section will illustrate the jigsaw in detail.

8.2.2 Jigsaw

The jigsaw was first proposed by Aronson in the 1970s (Aronson et al. 1978). The procedure of jigsaw includes three steps. First, learners are divided into different groups. Every group member is assigned a specific sub-topic which is to be learned individually. Second, the group members in different groups who are assigned the same sub-topic form the 'expert group'. The expert group members discuss the sub-topics and solve the problems. They become experts in that sub-topic after they have studied it. Third, the expert group members break up and go back to their former groups. They share what they have learned and teach the rest of the group the expert sub-topics (Berger and Hänze 2015; Looi et al. 2008). Thus, all of group members learned all sub-topics.

The characteristics of the jigsaw method include the following. First, learners form home groups and expert groups so that they can discuss the same topics and share their discussions with others. Second, home groups are formed by students who have different levels in learning achievements. Every student in home groups is responsible for one sub-topic. The members who learn the same sub-topics form the expert group (Aronson and Patnoe 1997). Therefore, the main difference between jigsaw and other collaborative learning strategies is that jigsaw enables every member to be responsible for one part of the task involved in the collaborative learning (Huang et al. 2014). It is clear that two crucial elements of collaborative learning are closely related to jigsaw (Looi et al. 2008). One is positive interdependence, another is individual accountability. Positive interdependence refers to "what helps one group member helps all group members and what hurts one group member hurts all" (Lai and Wu 2006). Individual accountability is defined thus, "the team's success depends on the individual learning of all team members" (Slavin 1987). Therefore, jigsaw can promote knowledge interdependence and individual accountability in collaborative learning.

Jigsaw has been widely applied to many subjects including literature, science, and social studies (Slavin 1995). The positive influence and the effectiveness of jigsaw have been well documented in previous studies. Jigsaw has been shown to inspire students' motivation (Hänze and Berger 2007; Johnson and Johnson 2009) and create a cooperative climate (Aronson and Patnoe 1997). Jigsaw can increase learning performance and promote interpersonal communication skills (Slavin 1989). Jigsaw can also help students to think independently, express clearly, and explore actively (Huang et al. 2014).

However, there are found to be some disadvantages with the jigsaw method. First, jigsaw decreases the amount of shared knowledge and common ground since every group member only learned about one sub-topic, which hinders knowledge sharing and integration (Buchs et al. 2004; Deiglmayr and Spada 2011). Common ground is very crucial for productive and successful collaborative learning (Beers et al. 2005; Noroozi et al. 2013). Second, learners who adopted the jigsaw method have been found to acquire less knowledge than learners using other collaborative learning methods (Berger and Hänze 2009; Moreno 2009). Third, Deiglmayr and Schalk (2015) posited that strong knowledge interdependence cannot optimally help learners to benefit from collaborative learning. Therefore, this study adopted the modified jigsaw method to overcome the abovementioned disadvantages.

8.3 Methodology

8.3.1 Participants

In this study, a total of 36 undergraduates voluntarily participated. All the participants were recruited by posters on campus. Among the 36 undergraduates, 34 of them were female and only two of them were male, with 35 % of them majoring in educational technology and the rest in pedagogy. They were randomly assigned into an experimental group and a control group. Half of them participated in the experimental group and half of them were in the control group. However, one student did not complete the task because he could not login to the system. Finally, only 17 undergraduates were in the control group and 18 in the experimental group.

8.3.2 Collaborative Learning Task

The topic of the collaborative learning task originated from educational statistics. The following is the description of the task.

The teacher Zhao has been a teacher for 30 years in an elementary school. Now, she is also a maths teacher of two classes in Grade 3. At the end of the semester, two classes took a maths examination.

- Sub-task 1: Please help the teacher Zhao to analyze the scores of two classes by different statistical methods and statistical charts.
- Sub-task 2: The school had an opportunity to attend an international summer camp. Only one student can attend this summer camp. Now three students applied to attend it. Please help the teacher find two solutions to how to select only one student.
- Sub-task 3: Please analyze whether there is any significant difference in learning achievements between the two classes.

The final group product included the solutions of the abovementioned problems and a concept map closely related to educational statistics.

8.3.3 Measuring Tools

The measuring tools in this study included the pre-test, post-test, and questionnaires of task cohesion and collective efficacy.

The pre-test and post-test aimed to examine prior knowledge and group performance. The test items of the pre-test were the same as the post-test. There were five open-ended questions in both the pre-test and post-test, giving a perfect score of 50. Both the pre-test and post-test were evaluated by two raters.

The questionnaire of task cohesion and collective efficacy were developed by Zheng et al. (2014). The questionnaire of task cohesion consisted of seven items with 5-point Likert scale, such as "Every group member made great contribution to the collaborative learning task". The Cronbach's α value of the task cohesion questionnaire was 0.862, indicating good reliability.

The questionnaire of collective efficacy consisted of 10 items with a 5-point Likert scale. For example, "Our group can complete the most difficult task during collaborative learning processes". Cronbach's α value for the collective efficacy questionnaire was 0.866, implying good reliability.

8.3.4 Procedure

This experiment was conducted in the labs in one university in order to examine the effectiveness of the modified jigsaw script. Figure 8.1 shows the procedure for the

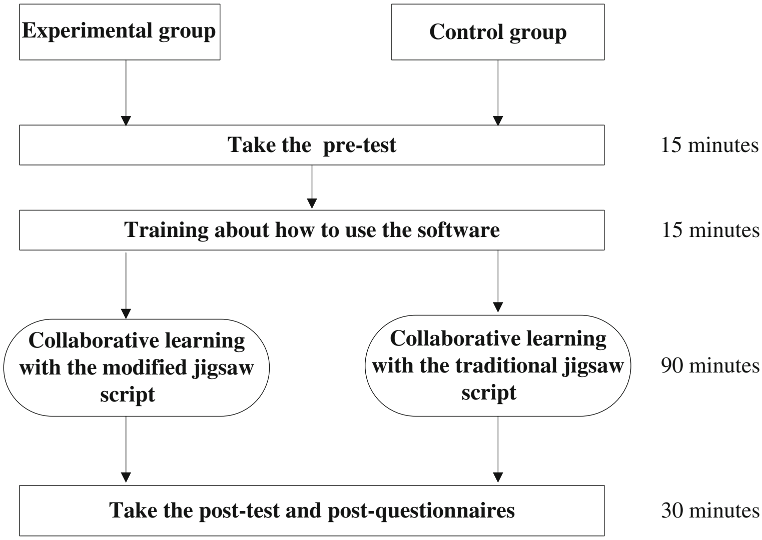

Fig. 8.1 The experimental procedure

experiment. Before the experiment, 35 participants were administered to the pre-test to examine their prior knowledge. After that, training regarding how to use *Cmaptools* was conducted for 15 min. Subsequently, the experiment group conducted online collaborative learning with the modified jigsaw, and the control group conducted online collaborative learning with the traditional jigsaw script. This phase lasted for about 90 min. Finally, all the participants took the post-test and post-questionnaires for 30 min.

Figure 8.2 shows the procedure taken during the traditional jigsaw. For example, let us take the three groups. In the first phase, every group member (M1, M2, and M3) in home group A, B, and C individually learned about one sub-task. In the second phase, the three members who completed the same sub-task in groups A, B, and C formed the expert group and conducted collaborative learning. Thus, three expert groups were formed. Every expert group discussed and solved one sub-task. In the third phase, all the members went back to their home group and conducted collaborative learning again. They shared what they learned about one sub-task and were taught the other sub-tasks by their peers.

Figure 8.3 shows the procedure taken during the modified jigsaw. In the first phase, every group member (M1, M2, and M3) in home groups A, B, and C individually learned about three sub-tasks. In the second phase, the members (M1) of the three groups formed the first expert group and conducted collaborative learning. The members (M2) of the three groups formed the second expert group, and the members (M3) of the three groups formed the third expert group. They conducted collaborative learning to share what they learned from the three sub-tasks. In the third phase, all of members went back to home group to conduct collaborative learning again and complete three sub-tasks.

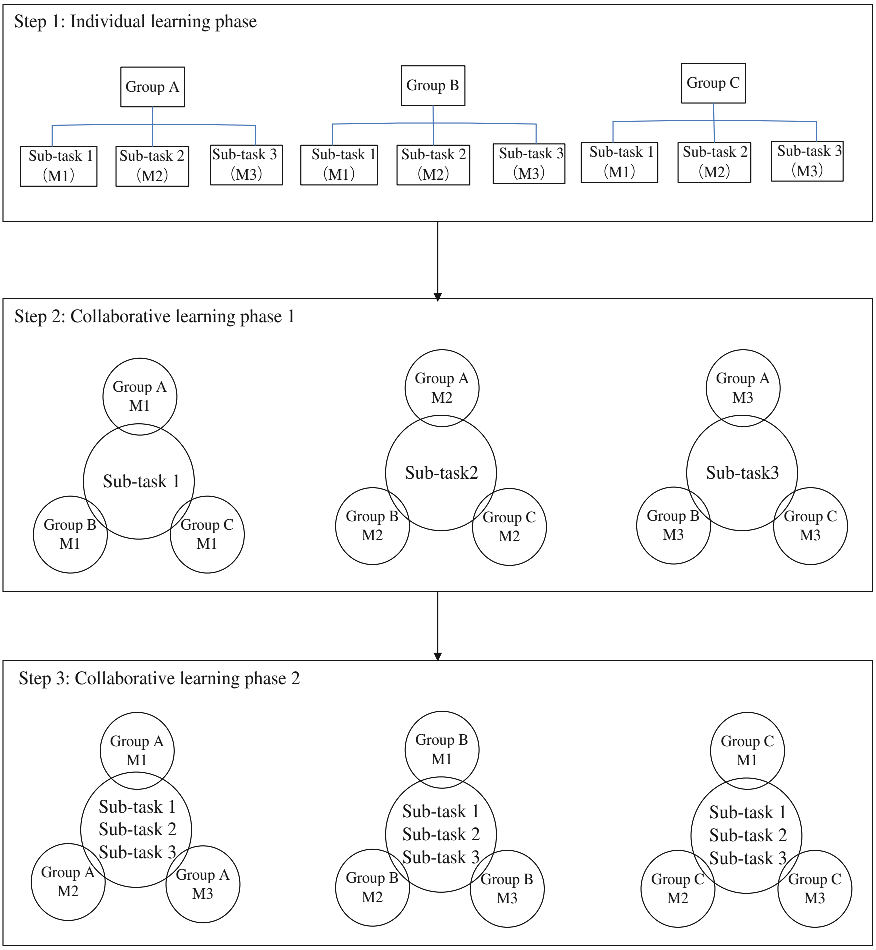

Fig. 8.2 The procedure of the traditional jigsaw method

8.4 Results

8.4.1 Analysis of Group Performance

One of the research purposes in this study was to examine the influence of the modified jigsaw scripts on group performance. The Levene test was performed to examine the homogeneity of variance (Conover 1998) and the Shapiro–Wilk test for examining the normality of distribution (Shapiro and Wilk 1965).

In terms of the pre-test, the results demonstrated that the *p*-values for the Levene test and the Shapiro–Wilk test were 0.647 and 0.294, respectively. This indicated that the data of pre-test had homogenous variances following a normal distribution

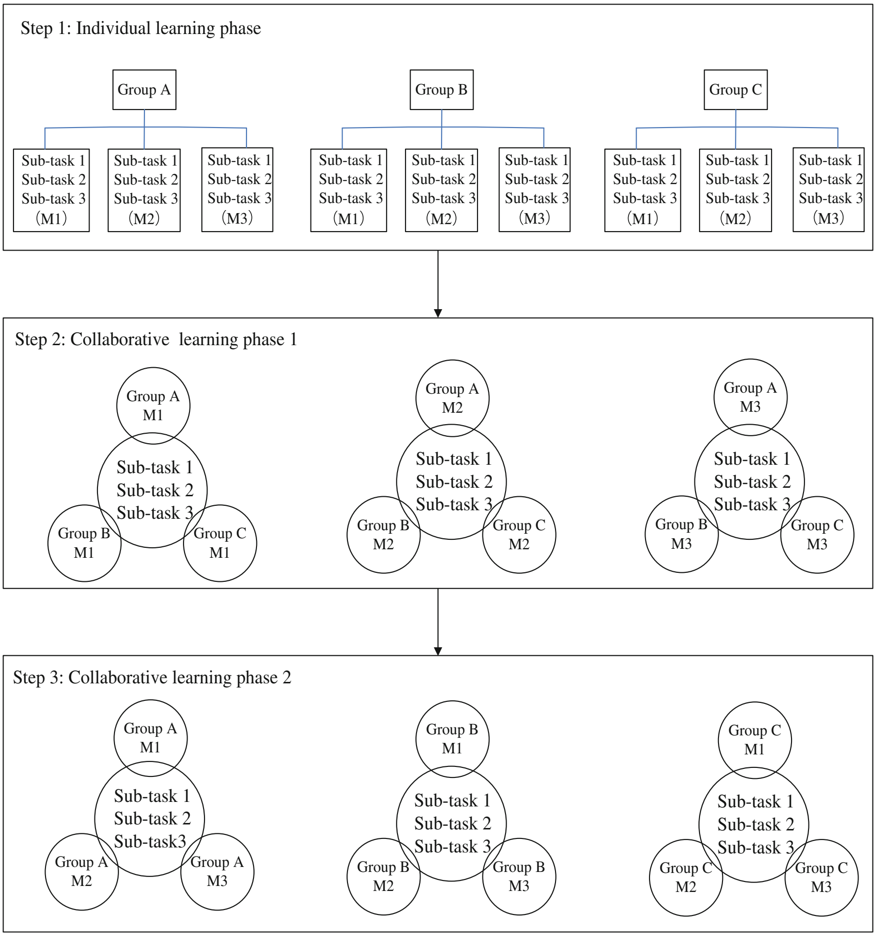

Fig. 8.3 The procedure of the modified jigsaw method

of data. With respect to the post-test, the results showed that the *p*-values for the Levene test and the Shapiro–Wilk test were 0.853 and 0.560, respectively. This indicated that the data of post-test had homogenous variances following a normal distribution of data. Therefore, the data could be analyzed with analysis of covariance (ANCOVA).

The findings indicated that the mean values and standard deviations of the pre-test for the experimental group were 12.78 and 7.07, and 13.12 and 6.61 for the control group, respectively. In terms of the pre-test, it was found that there was no significant difference between the experimental group and control group ($t = 0.147$, $p > 0.05$). This result indicated that the experiment group and control group had equivalent prior knowledge.

Table 8.1 shows the result of ANCOVA for the post-test. The result indicated that there was a significant difference in post-test between the experimental group and control group ($F = 4.38$, $p < 0.05$). That is to say the groups who conducted the modified jigsaw demonstrated better learning performance than those who conducted the conventional jigsaw approach.

8.4.2 Analysis of Task Cohesion

Since it was a new experience for the students to conduct the modified jigsaw activity, it was very interesting to examine task cohesion. Table 8.2 shows the *t*-test result for task cohesion. The means and standard deviations of the task cohesion were 3.94 and 0.71 for the control group, and 4.68 and 0.37 for the experimental group. It was very clear that there was significant difference in task cohesion between the experimental group and control group ($t = -3.819$, $p < 0.01$). These results indicated that the modified jigsaw can improve task cohesion.

8.4.3 Analysis of Collective Efficacy

Table 8.3 shows the *t*-test result for collective efficacy. The means and standard deviations of the collective efficacy were 3.51 and 0.64 for the experimental group and 4.23 and 0.43 for the control group.

The *t*-test result indicated that there was significant difference in collective efficacy between the experimental group and control group ($t = -3.936$, $p < 0.01$). This finding revealed that the modified jigsaw can improve collective efficacy.

Table 8.1 ANCOVA result of the post-test

Group	*N*	Mean	Standard deviation	*F*	*p*
Control group	17	15.76	7.73	4.38^{*}	0.04
Experimental group	18	20.00	8.48		

$^{*}p < 0.05$

Table 8.2 *t*-test result for task cohesion

Group	*N*	Mean	Standard deviation	*t*
Control group	17	3.94	0.71	-3.819^{**}
Experimental group	18	4.68	0.37	

$^{**}p < 0.01$

Table 8.3 *t*-test result for collective efficacy

Group	*N*	Mean	Standard deviation	*t*
Control group	17	3.51	0.64	-3.936^{**}
Experimental group	18	4.23	0.43	

$^{**}p < 0.01$

8.5 Discussion

This study examined the effectiveness of the modified jigsaw method in terms of group performance, task cohesion, and collective efficacy. The result demonstrated that the modified jigsaw method can significantly improve group performance in contrast with the traditional jigsaw method. This finding was consistent with Deiglmayr and Schalk (2015) who reported that the groups who learned using the modified jigsaw method acquired better learning performance than those who learned with the traditional jigsaw method. This result conformed with the study by Huang et al. (2014), which found that a jigsaw-based collaborative learning approach improved learning outcomes for mobile situated learning.

The finding also indicated that the modified jigsaw method was more effective than the traditional jigsaw method with respect to task cohesion. Task cohesion in this case refers to the group members' commitment to the group task (Wang and Hwang 2012). In terms of the modified jigsaw, it provided the opportunity for every group member to complete all of the sub-tasks. Thus, all the group members were obliged to complete all sub-tasks. The same task was helpful for establishing common ground and a shared understanding of the subject matter. Therefore, the modified jigsaw enhanced task cohesion further.

The result also demonstrated that the modified jigsaw method was more effective than the traditional jigsaw method with regard to collective efficacy. Collective efficacy is a group's shared beliefs in its ability to achieve goals (Bandura 1997). Previous studies indicated that collective efficacy had a positive effect on group processes (Bandura 2000; Lee and Farh 2004). Klassen and Krawchuk (2009) posited that collective efficacy was a socially shared cognition that progressed over time. In contrast with the traditional jigsaw, the modified jigsaw method improved collective efficacy because all of the group members had the same task and goals. Therefore, they had a shared belief that they could achieve the expected goals.

This study has some implications for teachers and practitioners. First, social interactions among group members are very crucial and important for successful collaborative learning. The learning outcomes of collaborative learning depend on how members interact with one other. Therefore, teachers should design elaborately the interaction processes before collaborative learning commences. There are many types of interactive strategies, such as brainstorming, jigsaw, peer assessment, and so on. Teachers should select the appropriate strategies according to the learning objectives and learning content. Second, common ground and shared cognition can facilitate social interactions during collaborative learning. Therefore, teachers need to design effective strategies to establish common ground and promote convergence. Many shared collaborative leaning tools are very appropriate for providing shared space, which is a pre-condition for collaborative learning to some extent. Third, task features had an influence on collaborative leaning outcomes. Weak task interdependence can also improve learning performance, group cohesion, and collective efficacy.

This study was constrained by several limitations. First, the sample size was small both in the experimental group and control group. Therefore, caution should be made when generalizing these research results. Future studies will expand the sample size to examine the effectiveness of the modified jigsaw method. Second, this study was conducted in the lab so as to ensure the validity of the experiment. Future studies will adopt the modified jigsaw method in natural learning settings. Third, this study only designed one task related to educational statistics. Future studies will design different kinds of tasks so as to explore the relationships between task features and interactive strategies.

8.6 Conclusion

This study investigated the impacts of the modified jigsaw method on group performance, task cohesion, and collective efficacy. The modified jigsaw is an effective method to script collaborative learning. The findings of this study revealed that the modified jigsaw can improve group performance, task cohesion, and collective efficacy. Therefore, the modified jigsaw is more effective than the traditional jigsaw. This study also implied that interactions among learners are a central issue for productive collaborative learning. Future studies will conduct the modified jigsaw in different learning contexts, such as in mobile learning environments.

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Chapter 9
Facilitating Collaborative Learning Through Peer Assessment APP: A Case Study

Abstract It has become common practice to adopt collaborative learning in the field of education. Among different collaborative learning strategies, peer assessment is one of the most effective strategies to improve learning performance and higher order thinking skills. Self-efficacy and motivation are two important dimensions of psychology in peer assessment. This study aims to investigate peer assessment, self-efficacy, and motivation as well as the role of feedback. In total, 48 undergraduates participated in this study and they conducted two-round peer assessments via a developed APP (Application). The results indicated that students with higher intrinsic motivation tended to have higher self-efficacy in peer assessment. Cognitive feedback and concrete suggestions were the most effective for improving learning performance in peer assessment. The implications and limitations of this study can contribute to the implementation of peer assessment in future studies.

Keywords Collaborative learning · Peer assessment · Self-efficacy · Motivation · Feedback

9.1 Introduction

Peer assessment has been widely acknowledged as an effective strategy that helps students make reflections on their learning processes (Lin et al. 2011) and improves their learning achievements (Lai and Hwang 2015). There are many advantages in terms of conducting peer assessment activities. For example, peer assessment can foster student's critical thinking skills (Chao et al. 2014; Lynch et al. 2012). Liu and Li (2014) revealed that peer assessment was helpful in enhancing learners' meta-cognitive awareness. In addition, peer assessment can engage assessors in evaluating their peers' work and providing feedback (Nicol et al. 2014). Learners benefited from peer assessment activity because it provided good opportunities for explaining, summarizing, and reflecting upon the learning processes (Chang et al. 2014).

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In recent years, mobile technologies have developed rapidly and provided good potential for promoting learning. Instant facilities provided by mobile technologies can enable learners to interact with peers or teachers synchronously (Shih et al. 2010). Learners can obtain learning materials and share ideas anytime and anywhere via mobile technologies (Chao et al. 2014). Moreover, Cizek (2010) posited that technology enhanced assessment can provide real-time feedback and formative assessment so as to decrease teachers' workloads. Therefore, researchers have developed mobile peer assessment to submit products, evaluate peers' work, and provide feedback (Chao et al. 2014; Lai and Hwang 2015). However, previous studies paid less attention to the psychology traits and the role of feedback in peer assessment. Hence, this study attempts to investigate peer assessment self-efficacy and motivation as well as the role of feedback messages.

9.2 Literature Review

9.2.1 Peer Assessment

Peer assessment is an instructional method that aims to engage learners in evaluating their peers' work (Topping 2009). In addition, learners need to revise their own work based on peer feedback. Therefore, peer assessment includes two important activities: one is evaluation of peers' work, another is revision of self-work (Chen and Tsai 2009; Smith et al. 2002). Peer assessment provides learners with opportunities to make meaning, reflect on their own ideas, share their understanding, and revise misconceptions (Roscoe and Chi 2007).

Previous studies have reported that peer assessment can improve learning performance. For example, Tsai and Chuang (2013) found structured online peer assessment was helpful for improving learners' writing performance. A similar finding was also reported by Joordens et al. (2009) who found that learners' writing skills were improved after peer assessment. In addition, peer assessment can arouse the interest and motivation of learners. Shih (2011) found that learners' interest in English writing was aroused, and their motivation to write inspired, as a consequence of peer assessment. Furthermore, peer assessment can increase learners' engagement (Bloxham and West 2004) and enhance critical thinking skills (Sims 1989).

Furthermore, Cheng et al. (2015) addressed that what types of peer feedback learners receive was the most important issue in peer assessment. Previous studies also indicated that negative feedback may induce negative emotional responses in peer assessment (Cheng et al. 2014). Therefore, some learners cannot benefit from feedback messages via peer assessment. Thus, which types of feedback message are valuable for learners still needs to be explored (Nelson and Schunn 2009). Based on the previous studies, it was found that there were three types of feedback, namely cognitive, affective, and meta-cognitive feedback. Lu and Law (2012) reported that cognitive feedback was the most common type of feedback. Some studies reported that cognitive feedback was more helpful for learners using peer assessment to improve learning performance (Cho and Cho 2010; Hattie and Timperley 2007). Some studies found that positive affective feedback was critical for improving learning outcomes (Tseng and Tsai 2007). While Chen and Tsai (2009) found that meta-cogntive feedback was significantly related to learning performance in peer assessment. Therefore, the results of previous studies varied from one study to another. Thus, this study further examines the role of feedback messages in peer assessment so as to gain more insights into the nature of feedback.

9.2.2 Self-efficacy

Self-efficacy was defined as the specific beliefs about what one can do (Bandura 1982). Bandura (1997) believed that self-efficacy had great influence on one's motivation, emotions, thought patterns, and behaviors. Researchers have addressed the idea that self-efficacy is a determining factor in learning performance (van Dinther et al. 2011). Students with high self-efficacy often fulfill their potential (Sööt and Leijen 2012).

Previous studies have demonstrated that self-efficacy was closely related to learning performance (Bell and Kozlowski 2002; Kagima and Hausafus 2000). This means that a higher self-efficacy can lead to better learning performance. Multon et al. (1991) found that self-efficacy was significantly related to learning performance in different contexts via the meta-analysis of 39 studies. Even in a web-based learning environment, self-efficacy still correlated to learning performance (Wang and Newlin 2002).

In addition, previous studies also revealed the relationships between self-efficacy and peer assessment. De Grez and Valcke (2013) found that self-efficacy was positively related to raters' scores. Tseng and Tsai (2010) also indicated that students with higher self-efficacy were more engaged in peer assessment. Hsia et al. (2015) revealed that self-efficacy was significantly related to dance skills in arts courses. To sum up, self-efficacy can affect the quality of peer assessment to some extent.

9.2.3 Motivation

Motivation refers to individuals' internal states that direct their goals and activate their behaviors (Franken 2006). Motivation was characterized as those achievement goals that closely relate to the reasons for performing academic-related tasks (Clayton et al. 2010). Ryan and Deci (2000) posited that intrinsic motivation and extrinsic motivation are two dimensions of motivation. Students will make greater effort when they are intrinsically motivated (Ames and Archer 1988). Tseng and Tsai (2010) revealed that learners with higher intrinsic motivation could perform peer assessment activities better. Furthermore, Kane et al. (2013) posited that motivation can keep students involved in a high level of dance performance. Therefore, motivation was a very important factor encouraging students to learn better (Ryan and Deci 2000). Previous studies have indicated that peer assessment can significantly promote students' motivation in arts course (Hsia et al. 2015). Furthermore, intrinsic motivation was also closely related to self-efficacy and dance skill performance in peer assessment activities (Hsia et al. 2016).

The purpose of this study is twofold. First, it aims to investigate how self-efficacy and motivation correlate to each other in peer assessment activities. Second, it aims to explore the role of peer feedback. Thus, the research questions are formulated as follows:

1. What are the relationships between self-efficacy and motivation in peer assessment?
2. Which kind of feedback is more helpful for students?
3. Are there any differences in feedback messages between the first round of assessment and the second round of assessment?

9.3 Peer Assessment APP

In order to facilitate students to conduct peer assessment, an APP on peer assessment was developed. The main functionalities included:

- Uploading group products (see Fig. 9.1).
- Viewing the products of every group (see Fig. 9.2).
- Peer assessment based on the criterion for the first time (see Fig. 9.3).
- Viewing the results and providing feedback to peers (see Fig. 9.4).
- Revising group products and resubmitting.
- Peer assessing based on the criterion for the second time.

The system randomly assigned members of three groups to be assessors for the first round assessment. In the second round assessment, the system assigned the same members to conduct peer assessment.

9.4 Methodology

9.4.1 Participants

Participants enrolled on the multimedia technology and webpage making course worth 4 academic credits. In total, 48 volunteers participated in this study, with 15 % of them being male and 85 % of them female. The average age of the participants was 19 years, and they majored in Chinese literature or communication theory. All the participants were randomly assigned into 12 groups of 4 people.

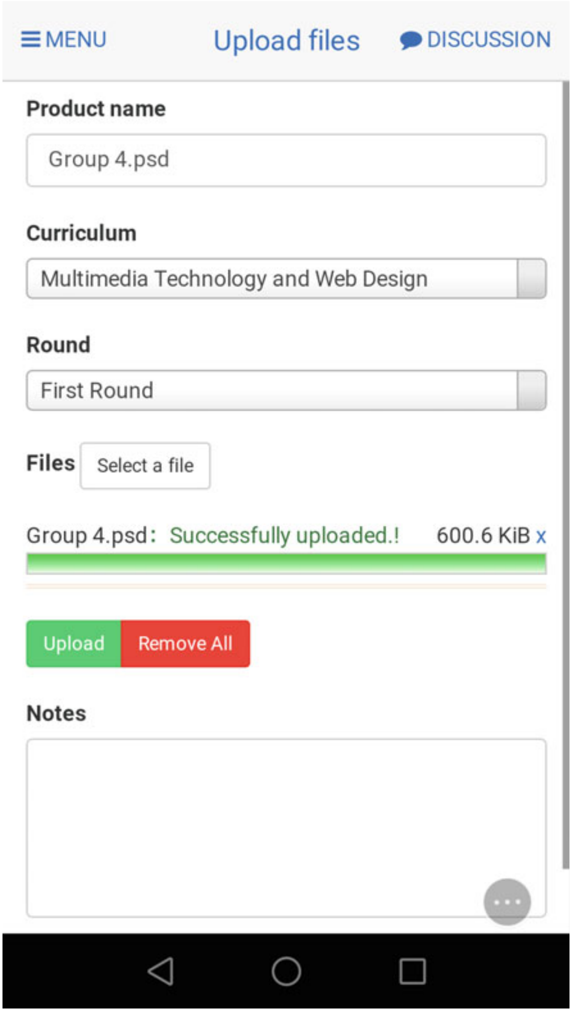

Fig. 9.1 Uploading the group product

They all had prior experience of collaborative learning. Therefore, no specific training was implemented before collaborative learning. Furthermore, group members in every group were not familiar with each other.

9.4.2 Collaborative Learning Task

The collaborative learning task was to make a poster using Photoshop CS5. Every group completed the same task over a period of three weeks. Participants could discuss online via a collaborative learning platform. They could also discuss

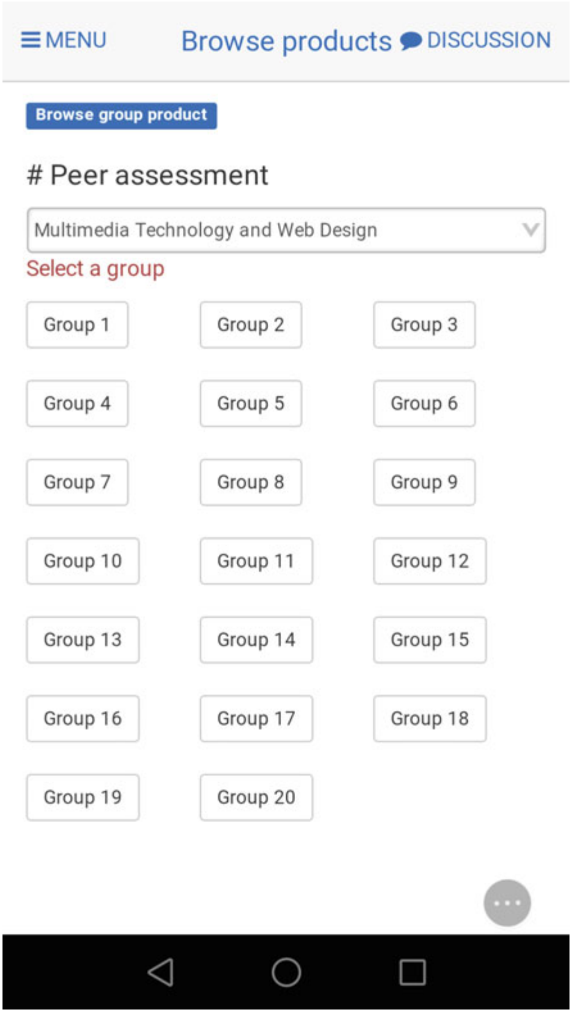

Fig. 9.2 Viewing the products of all groups

face-to-face with their group members. Initially, they were informed that the posters would be twice evaluated by their peers.

9.4.3 Measuring Tools

The peer assessment self-efficacy questionnaire was adapted from Tseng and Tsai (2010). It consisted of an evaluating scale, receiving scale, and reacting scale. There were 15 items with a 5-point Likert score ranging from "not at all confident" to "very confident". The evaluating scale, the receiving scale, and reacting scale consisted of

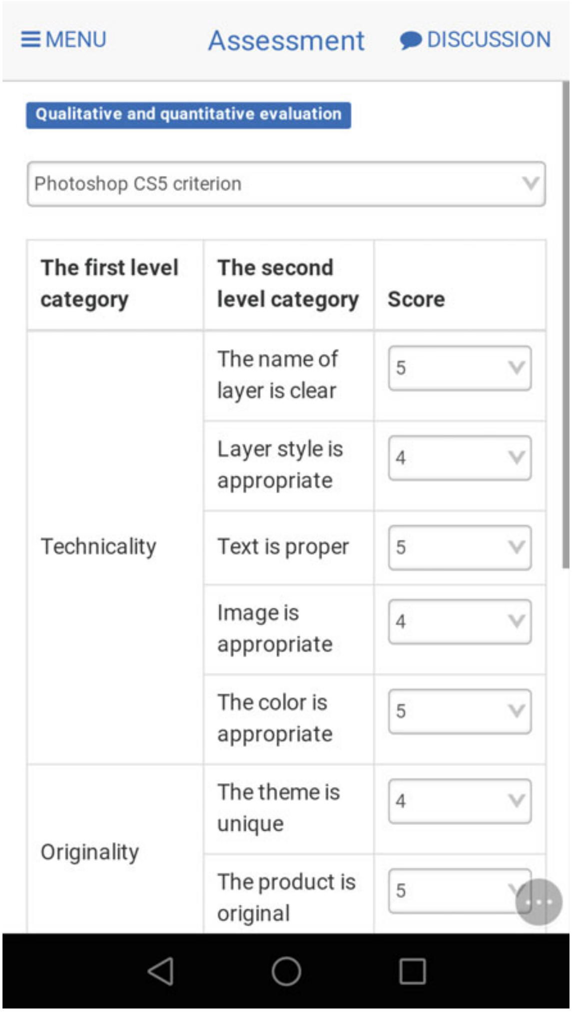

Fig. 9.3 Peer assessment

six items, four items, and five items, respectively. The evaluating scale measured learners' confidence in evaluating others' products. For example, "In the peer assessment activity, I can give helpful opinions or suggestions when I review peers' work." The receiving scale measured learners' confidence in receiving feedback from their peers and accepting their own disadvantages. For example, "In the peer assessment activity, I can examine the problem in my own work when I get comments from peers." The reacting scale measured learners' confidence in reacting to peer feedback. For example, "After reading comments in the peer assessment activity, I can improve my work with a good strategy." The overall Cronbach's alpha coefficient for the three scales was 0.90, indicating excellent reliability.

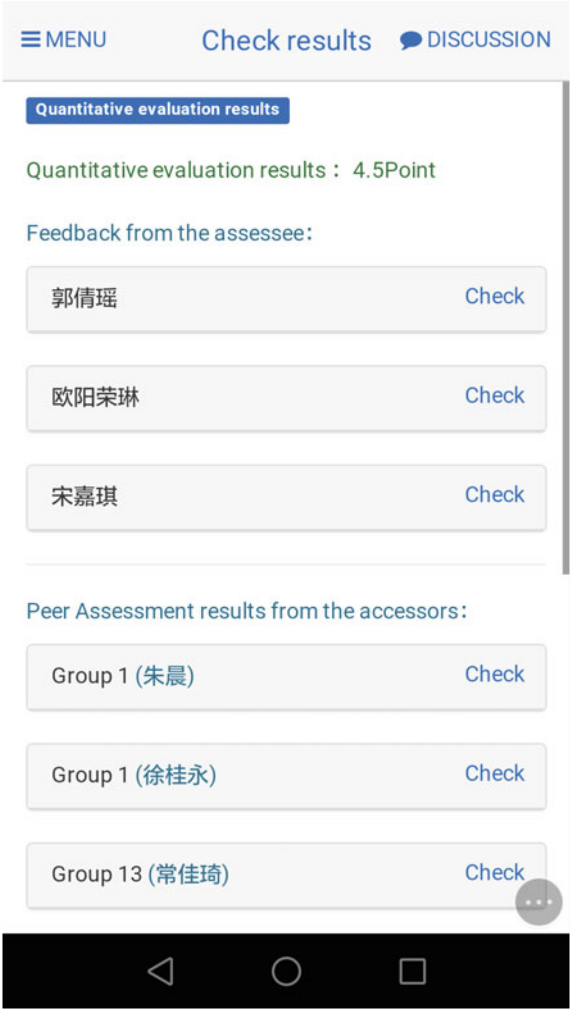

Fig. 9.4 Viewing the results

The peer assessment motivation questionnaire was also adapted from Tseng and Tsai (2010). It consisted of an intrinsic motivation scale and an extrinsic motivation scale. There were 12 items with a 7-point Likert score ranging from "strongly disagree" to "strongly agree". The intrinsic motivation scale measured the internal attribution for peer assessment. For example, "In peer assessment, I am triggered to learn more if I have the chance to review peers' work." The extrinsic motivation scale measured the external attribution for peer assessment. For example, "I turn in peer assessment just to meet the teachers' course requirements." The overall Cronbach's alpha coefficient for the two scales was 0.78, indicating good reliability. The role of feedback messages was investigated by four questions, as shown in the appendix to this chapter.

9.4.4 Procedure

The procedure for this study is as follows. First, all of the groups conducted collaborative learning and produced a poster using Photoshop CS5. Groups then uploaded group products to the peer assessment APP. Second, the system randomly assigned members of three groups. These members evaluated peer products based on the rubric, which included the dimension of text, color, layout, theme, and qualitative comments. Third, all of the groups revised their group products based on comments and suggestions. After that, each group resubmitted their revised products to the system. Fourth, the system assigned the same assessors to evaluate the group products. Therefore, the whole assessment included two rounds of peer assessment. Finally, all of the participants answered four questions (see the appendix at the end of this chapter) via the APP. Participants were then administered the peer assessment self-efficacy questionnaire and the peer assessment motivation questionnaire.

9.5 Results

9.5.1 The Relationships Between Peer Assessment Self-efficacy and Motivation

Table 9.1 shows the descriptive results of the peer assessment self-efficacy and motivation questionnaires. Table 9.2 shows the relationships between the evaluating scale, receiving scale, and reacting scale in the self-efficacy questionnaire. It was very clear that the evaluating scale was significantly related to the receiving scale ($r = 0.642$, $p < 0.01$) and reacting scale ($r = 0.697$, $p < 0.01$). The receiving scale was significantly related to the reacting scale ($r = 0.609$, $p < 0.01$). This result indicated that students with higher confidence in evaluating their peers' work tended to have greater confidence in receiving peer views and reacting to peer feedback. The learners with higher confidence in receiving peer views also tended to have higher confidence in making reactions to peer assessment.

Table 9.3 demonstrates the relationships between intrinsic motivation and extrinsic motivation. The results indicated that there was no significant relationships between intrinsic motivation and extrinsic motivation ($r = 0.127$, $p > 0.05$). This means learners that had higher intrinsic motivation did not tend to have higher extrinsic motivation in peer assessment.

Table 9.1 The descriptive statistics result of peer assessment

	Means	Standard deviation
Evaluating scale	5.39	0.89
Receiving scale	4.91	0.73
Reacting scale	5.33	1.12
Intrinsic motivation scale	5.50	0.83
Extrinsic motivation scale	4.48	1.08

Table 9.2 The relationships between evaluating scale, receiving scale, and reacting scale

	Evaluating scale	Receiving scale	Reacting scale
Evaluating scale	1	0.642^{**}	0.697^{**}
Receiving scale	0.642^{**}	1	0.609^{**}
Reacting scale	0.697^{**}	0.609^{**}	1

$^{**}p < 0.01$

Table 9.3 The relationships between intrinsic motivation and extrinsic motivation

	Intrinsic motivation scale	Extrinsic motivation scale
Intrinsic motivation scale	1	0.127
Extrinsic motivation scale	0.127	1

Table 9.4 shows the relationships between peer assessment self-efficacy and motivation. The findings revealed that learners with higher intrinsic motivation were inclined to have higher confidence in receiving peer views ($r = 0.288$, $p < 0.05$) and reacting to peer feedback ($r = 0.347$, $p < 0.01$). However, there was no significant relationship among extrinsic motivation and self-efficacy scale.

9.5.2 *Clustering Analysis of Learners' Self-efficacy in Peer Assessment*

Table 9.5 shows the clustering results of learners' peer assessment self-efficacy. It was very clear that there were three clusters in terms of learners' peer assessment self-efficacy. Cluster 1 had low self-efficacy, Cluster 2 had medium self-efficacy, and Cluster 3 had high self-efficacy. In addition, there was significant difference in evaluating peer work, receiving peer comments, and reacting to peer assessment among these three clusters.

Table 9.4 The relationships between peer assessment self-efficacy and motivation

	Evaluating scale	Receiving scale	Reacting scale
Intrinsic motivation scale	0.144	0.288^{*}	0.374^{**}
Extrinsic motivation scale	0.264	0.272	0.153

$^{*}p < 0.05$, $^{**}p < 0.01$

Table 9.5 The clustering results of learners' peer assessment self-efficacy

Scales	Total ($n = 48$) Mean (Standard deviation)	Cluster (1) ($n = 5$) Mean (Standard deviation)	Cluster (2) ($n = 31$) Mean (Standard deviation)	Cluster (3) ($n = 12$) Mean (Standard deviation)	*F* (ANOVA)
Evaluating	5.38 (0.88)	4.00 (1.24)	5.25 (0.52)	6.30 (0.47)	26.93^{**}
Receiving	4.91 (0.72)	3.80 (0.73)	4.88 (0.59)	5.43 (0.46)	13.98^{**}
Reacting	5.33 (1.12)	2.88 (1.03)	5.25 (0.39)	6.56 (0.37)	104.72^{**}

9.5.3 The Role of the Feedback Message

Table 9.6 shows the results of the feedback message over two rounds of the peer assessment. Overall, most learners believed that peer comments were very useful for improving group products. In the first round of peer assessment, 57.81 % of learners posited that peer comments were very useful. In the second round of peer assessment, it sharply increased into 95.08 %. Furthermore, there was significant difference between the first round and the second round ($\chi^2 = 20.04$, $p < 0.01$). This finding indicated that learners acknowledged the usefulness of peer assessment.

As shown in Table 9.6, 67.19 and 62.3 % of learners believed that cognitive comments were the most effective and useful in the first round and second round, respectively. Furthermore, there was no significant difference between the first round and second round ($\chi^2 = 0.21$, $p > 0.05$). The finding implied that cognitive comments were the most effective and helpful for improving group products.

The findings also revealed that concrete suggestions were the most effective in the first round and second round of peer assessment, accounting for 31.33 and

Table 9.6 The feedback message over two rounds of peer assessment

Items		The first round (%)	The second round (%)	χ^2
What do you think of the peer assessment?	Very useful	57.81	95.08	20.04
	Useless	42.19	4.92	1.17
The effectiveness of comments	Cognitive comments	67.19	62.3	0.21
	Meta-cognitive comments	26.56	32.79	0.16
	Affective comments	06.25	4.92	0.005
The effectiveness of feedback message	General advice	4.82	4.61	0.0003
	Concrete suggestions	31.33	32.24	0.01
	Positive comments or praise	10.24	15.79	0.26
	Negative comments or criticism	14.46	10.53	0.13
	Comments on methods or strategies	23.49	19.74	0.14
	Comments on reflecting on the group products	15.66	17.11	0.02
What have you learned from peer comments?	Domain knowledge and skills	36.84	32.37	0.21
	Methods or strategies	30.08	33.81	0.13
	Positive feelings	21.05	19.42	0.02
	Be more interested in what I have learned	12.03	14.39	0.04

32.24 %, respectively. In addition, there was no significant difference between the first round and second round ($\chi^2 = 0.01$, $p > 0.05$).

As shown in Table 9.6, 36.84 and 32.37 % of learners believed that domain knowledge accounted for the greatest percentage in terms of benefitting from peer comments. Moreover, there was no significant difference between the first round and second round ($\chi^2 = 0.21$, $p > 0.05$).

9.6 Discussion

This study investigated the relationships between peer assessment self-efficacy and motivation as well as the role of feedback messages. The questionnaires of peer assessment were adopted to measure self-efficacy and motivation. The results indicated that learners who had high scores in evaluating peer work, receiving peer views, and reacting to peer feedback had high self-efficacy in peer assessment. This finding was consistent with Barbeite and Weiss (2004) who found that people who had more confidence felt less anxious when they engaged in computer-based activities. As Bandura (1997) stated, learners who had high self-efficacy tended to complete tasks that were beyond their abilities.

The findings also revealed that learners' intrinsic motivation was positively related to their self-efficacy in peer assessment. This result was in line with Tseng and Tsai (2010) who found that intrinsic motivation was more related to self-efficacy than extrinsic motivation. This result also corroborated that intrinsic motivation played a crucial role in fostering self-efficacy (Bandura and Schunk 1981; Harter 1981). This finding also implied that only when students learned with intrinsic motivation, will they have a better learning performance.

The results also found that peer assessment was very useful for improving group products. Among different kinds of feedback information, cognitive feedback and concrete suggestions were the most effective and useful in peer assessment. This finding was consistent with previous studies (Hattie and Timperley 2007), indicating that cognitive feedback led learners to better understand subject matter. The result were similar to the findings of Cheng et al. (2015) study which revealed that cognitive feedback was more useful for improving students' learning gains than affective and meta-cognitive feedback. With respect to the type of feedback message, similar to Cheng et al. (2015) as well as Strijbos et al.'s (2010) findings, it was found that concrete suggestions were more helpful with enhancing learning performance.

This study had several implications for practitioners. First, peer assessment is an effective and useful strategy to engage students in collaborative learning. Peer cognitive feedback was more useful for improving group products than affective feedback and meta-cognitive feedback. Therefore, teachers should design peer assessment activities and implement them in different subjects. In addition, although cognitive feedback is important, affective and meta-cognitive feedback are also essential during collaborative learning. Positive feedback can enhance learners' confidence and self-efficacy. Second, learners' intrinsic motivation is the most important for improving self-efficacy and learning performance. Therefore, teachers should inspire students' intrinsic motivation by encouragement or other learning activities. Third, high self-efficacy can improve the quality of peer assessment. Therefore, self-efficacy is another important factor to improve learning performance. Students who have high self-efficacy tend to have a good learning performance, which in turn can improve self-efficacy further.

This study was constrained by several limitations. First, the sample size of the study was small. Future studies will expand the sample size to examine the effectiveness of peer assessment. Second, this study only selected one task to investigate the relationships between self-efficacy and motivation as well as the role of feedback. Future studies will design different kinds of tasks to generalize the results. Finally, the study lasted for three weeks. It was very interesting to conduct longitudinal study in order to track how self-efficacy and motivation evolve over time.

9.7 Conclusion

This study aimed to probe peer assessment self-efficacy and motivation as well as the role of feedback facilitated by peer assessment (APP). The main findings of this study indicated that learners' intrinsic motivation was positively related to their self-efficacy in peer assessment. In addition, peer assessment was very effective at improving students' learning performance. In contrast with affective feedback and meta-cognitive feedback, cognitive feedback played a crucial role in peer assessment. Learners preferred the specific suggestions that really helped them to improve the quality of their products. This study shed light on the psychological traits of peer assessment and highlighted real-time feedback in peer assessment.

Appendix

Questions about peer assessment

1. Overall, what do you think of the peer assessment?

   A. Very useful
   B. Useless

2. Which kind of comment is the most useful for improving group products?

   A. Cognitive comments
   B. Meta-cognitive comments
   C. Affective comments

3. Which kind of peer feedback messages are the most useful for improving group products?
   A. General advice
   B. Concrete suggestions
   C. Positive comments or praise
   D. Negative comments or criticism
   E. Comments on skills, methods, or strategies
   F. Comments on reflecting on the group products
4. What have you learned from peer comments?
   A. Domain knowledge or skills
   B. Methods or strategies
   C. Positive feelings
   D. Be more interested in what I have learned

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Chapter 10
Collaborative Inquiry Learning Among Four Elementary Schools in China: A Case Study

Abstract The aim of this study is to examine students' learning attitudes toward science, interaction patterns, knowledge advancement, and group products in collaborative inquiry learning. The 196 participants were taken from Grade 4 in four elementary schools in China. They were randomly assigned into 48 groups by their teachers. For each school, there were 12 groups who conducted collaborative inquiry learning face-to-face and online for 3 months. By the end of the collaborative inquiry learning, all of the participants shared and presented their experiences, artifacts, and outcomes. The results indicated that learning attitudes toward science improved after collaborative inquiry learning. In terms of interaction patterns, two teachers were positioned at center of the network and played very crucial roles in collaborative inquiry learning. With respect to the level of knowledge advancement, the discourse was scientific but superficial. Most learners could not explain the reasons, relationships, or mechanisms about tools in daily life. The implications for educators and practitioners as well as suggestions for future studies are also discussed.

Keywords Collaborative learning · Inquiry-based learning · Interaction pattern · Knowledge building · Learning attitude

10.1 Introduction

Collaborative inquiry learning has gained increasing attention in recent years. Nelson and Slavit (2008) posited that collaborative inquiry learning has been a dominant structure for educators in the twenty first century. Collaborative inquiry learning aims to help learners understand how to generate scientific knowledge and recognize that knowledge building is a joint task (Urhahne et al. 2010). Collaborative inquiry learning puts emphasis on active learning by collaboratively asking questions, formulating, and examining hypotheses (Laru et al. 2012). Learners first proposed questions, then collaboratively investigated them with empirical data and evidence during a collaborative inquiry learning processes.

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Furthermore, the process of inquiry was also characterized as cyclic and iterative so as to refine theories or ideas (Hakkarainen 2002). In addition, collaborative inquiry learning provides a good opportunity for teachers and practitioners to share understanding about common topics (Donohoo 2013).

The purpose of this study is twofold. First, we aim to investigate the learning attitudes and the quality of group products after collaborative inquiry learning. Second, we aim to gain a better understanding of the characteristics of interaction patterns and knowledge building during collaborative inquiry learning. Therefore, the research questions are as follows:

1. Did students' learning attitude change after collaborative inquiry learning?
2. What were the characteristics of the interaction patterns during collaborative inquiry learning processes?
3. What were the characteristics of knowledge building with respect to knowledge advancement across discourse phases?
4. What was the quality of group products like after collaborative inquiry learning?

10.2 Literature Review

10.2.1 Inquiry-Based Learning

Inquiry is viewed as a scientist-like activity both inside and outside the classroom (Bybee 2006). Learners should be involved in proposing scientifically oriented questions, searching for information and evidence, developing a feasible plan, conducting inquiry activities, justifying explanations, and generating solutions during inquiry processes (National Research Council 2000). Inquiry oriented science has been regarded as an important teaching strategy for inspiring motivation, an interest toward science, and scientific abilities (Dewey 1944).

Inquiry-based learning is represented by learning activities that engage learners in solving problems to develop a range of inquiry related abilities (Little 2008). Inquiry-based learning is a set of teaching methods that provide research-focused processes for learners (Aditomo et al. 2013). Jonassen (2000) posited that learners were responsible for their own learning and forced to make judgements and decisions through inquiry-based learning. Inquiry-based learning can also facilitate problem-solving skills, communication skills, and reasoning abilities (Kreber 2006).

Many classrooms still remain centers for rote learning and regurgitated facts in many parts of the world (Harada and Yoshina 2004). However, inquiry-based learning has demonstrated many benefits for learners in contrast with rote learning. Learners can acquire new knowledge and consolidate their current understanding and competencies during inquiry-based learning processes (Sockalingam et al.

2011). Previous studies have reported that inquiry-based learning is helpful for improving learners' perceptions, satisfaction, and learning outcomes. For example, Zafra-Gómez et al. (2015) measured the impact of inquiry-based learning on learning outcomes and student satisfaction. They found that students were more involved in learning and acquired increased knowledge of subject matter during inquiry-based learning. Chen et al. (2014) found that after-school, inquiry-based learning acted as a facilitating agent for improving low achievers' affective perceptions of learning science and positive thinking. Hwang et al. (2013) reported that an inquiry-based mobile learning approach can lead to better learning achievement and less cognitive loading than traditional approaches. All in all, inquiry-based learning is found to facilitate higher order thinking skills and improve learning performance.

10.2.2 Collaborative Inquiry Learning

The benefits of collaborative learning have been well documented in the literature (Slavin 1996; Webb and Palincsar 1996). Discourse among group members can help them to clarify their thinking and consolidate their ideas (Hmelo-Silver et al. 2002). Collaborative learning also provides opportunities for co-constructing knowledge, comparing different opinions, as well as explaining plans, concepts, and ideas (Rozenszayn and Assaraf 2011). The zone of proximal development proposed by Vygotsky (1978) can account for the benefits of collaborative learning since peers offer zones of proximal development to each other. Collaborative learning is often applied with other pedagogies, for example inquiry-based learning. Inquiry-based learning is a learning process which involves finding solutions to problems. Inquiry-based learning can develop the ability to examine and accept or reject relationships between evidence and theories (Duschl and Osborne 2002). In addition, inquiry-based learning activities provide many good opportunities for solving complex and real-world problems, which in turn promotes learners to achieve a rich learning experience.

Collaborative inquiry learning originated from the demand of practicing inquiry in science education (National Research Council 1996) and the increasing proliferation of collaborative learning (Koschmann et al. 2001). Collaborative inquiry learning is the learning activity that allows group members to share their thoughts and prior knowledge in a collaborative way (Rozenszayn and Assaraf 2011). Dong and Guo (2013) integrated collaborative learning and inquiry-based learning into the undergraduate computer networking curriculum. They found that collaborative inquiry learning had a positive impact on students' learning outcomes and satisfaction.

Collaborative inquiry learning includes the following processes, namely, orienting and asking questions, generating hypotheses, making plans, investigating, analyzing and interpreting, modeling, evaluating, communicating, and predicting (Bell et al. 2010). During the orienting and asking questions process, learners posed new questions by themselves after observation. Formulating hypotheses was not very easy for most learners. Many found it took some time to generate a final hypothesis. Planning included the design of experiments in order to examine a proposed hypothesis. Investigating involved collaboratively collecting data and evidence. The phase of analyzing and interpreting included analyzing data and interpreting results to confirm whether a hypothesis was, or was not, validated. Model creation was a fundamental aspect of scientific learning (Schwarz and White 2005), which can help to create objects and their mutual relationships. During the process of evaluation, learners evaluated their results and made judgements about their research. The purpose of communicating was to share and present results among learners. Finally, learners make predictions and express their beliefs about the dynamics of a system (Bell et al. 2010).

10.2.3 Knowledge Building

Knowledge building is defined as the production and continual improvement of ideas of value to a community (Scardamalia and Bereiter 2003). Knowledge building is often viewed as knowledge creation by Bereiter and Scardamalia (1993). Scardamalia (2002) proposed there were 12 principles comprising knowledge building, namely, real ideas and authentic problems, improvable ideas, epistemic agency, collective responsibility for community, democratizing knowledge, idea diversity, knowledge building discourse, rising above, constructive use of authoritative sources, pervasive knowledge building, symmetric knowledge advance, and embedded and transformative assessment. These 12 principles have been applied by researchers and developers to design collaborative learning environments.

Knowledge building is also a pedagogical approach that puts emphasis on collective responsibility for knowledge advancement (Scardamalia 2002; Scardamalia and Bereiter 2006). This means that a collective has the responsibility to improve ideas and advance knowledge. Bereiter (2002) believed that making ideas explicit and public was very important and essential for communication and improving ideas. Therefore, discourse among group members can facilitate ideas to be public and explicit. In order to create new knowledge, discourse needs to design and improve theories, explanations, and proofs (Bereiter 2002).

In addition, teachers also play a very crucial role in facilitating knowledge building. Zhang et al. (2011) reported that sustaining principle-based innovation depends on teachers' abilities and adaptive expertise. Engaging teachers in reflecting on the adequacy of their knowledge and dealing with complex challenges can facilitate sustainable innovation (Bereiter and Scardamalia 1993). Previous studies also reported that teachers' continual learning (Rodgers 2002), collaboration and shared practice (Fogleman et al. 2006), and professional autonomy (Vescio et al. 2008) were helpful for developing knowledge building.

10.3 Methodology

10.3.1 Participants

The participants for this study numbered 196 Grade 4 pupils from four elementary schools located in Tianjin (2 schools) and Fuquan (2 schools). Of the 196 students, 49 % of them were female and 51 % were male. Their average age was 10 years. All of the participants were selected by four teachers who were involved in this study. Every teacher selected one class to be part of this study. The average number of students in each class was 49, which were randomly assigned into 12 groups of 4 or 5 pupils. The teachers in this study had a rich experience of inquiry-based learning.

10.3.2 Procedure

This study was conducted through both an online collaborative inquiry learning platform and face-to-face learning for a period of three months. The procedure comprised four phases. At the beginning of the study, every teacher selected one class and trained their students how to use the inquiry learning platform. The students in one class were randomly assigned into different groups. Then teachers introduced the task linked to collaborative inquiry learning face-to-face. The task of this study was to investigate the different kinds of tools available in daily life (see explanation below). Participants could select different tools based on their interests and prior knowledge. Every group selected one kind of tool and confirmed this with their teacher. The topics included transportation, communication tools, tableware, stationery, fire tools, network tools, and so on. In the second phase, every group designed and wrote research proposals after having had a discussion. The topics about the research proposal included the introduction, functionalities, and usage of such tools in daily life. The teacher reviewed and checked the research proposals after submission. Every group revised their proposals based on the teacher's comments and suggestions. In the third phase, every group conducted inquiry-based learning both face-to-face and online in order to complete the research task. Teachers interacted with students face-to-face and online. As a facilitator and supervisor, teachers also answered questions, proposed new questions, provided valuable suggestions, and sent kind reminders. Finally, every group in each class presented the final group product face-to-face. The final products were in the form of hand-copied newspaper. Both teachers and peers evaluated these final products based on the rubrics. Finally, all four elementary schools presented and shared their entire inquiry-based learning processes and group products via an online video conferencing system.

10.3.3 Data Collection and Analysis Method

In this study, the data sources included questionnaires, discussion transcripts from the forums, interaction data, and group products. With regard to data analysis methods, this study adopted surveys, social network analysis, and content analysis methods to analyze data across all four elementary schools.

In order to measure learning attitude, the study used an adapted questionnaire developed by Sung et al. (2015). It consisted of 25 items with a 5-point rating scheme. The Cronbach's α value for this questionnaire achieved 0.92.

In order to analyze interaction patterns, a social network analysis method was conducted via Gaphi 0.9. Gaphi is the leading visualization and exploration open-source software for social network analysis. For more details about Gaphi, please visit the website: https://gephi.org/.

In order to analyze the level of knowledge advancement, we adopted the coding scheme proposed by Zhang et al. (2011). As shown in Table 10.1, knowledge advancement included scientificness and complexity. Two raters coded all the discussion transcripts independently. The inter-rater agreement achieved 0.91. All of the discrepancies were discussed and solved.

In order to evaluate group products, we adapted the rubric developed by Lai and Hwang (2015). The rubric included four dimensions, namely word, space, color, and theme. The scores ranged from 1 to 3. Table 10.2 shows the criteria for group products.

Table 10.1 Coding scheme of knowledge advancement

Code		Explanation
Scientificness	Pre-scientific	Contains misconceptions and naive conceptual frameworks
	Hybrid	Contains misconceptions and some scientific information
	Basically scientific	Not precise, but applies a scientific framework
	Scientific	Consistent with scientific knowledge
Complexity	Unelaborated facts	Simple statements
	Elaborated facts	Elaboration of terms, phenomena, etc.
	Unelaborated explanations	Includes reasons, relationships, or mechanisms
	Elaborated explanations	Elaborations of reasons, relationships, or mechanisms

Table 10.2 Criteria for group products

Dimension	3	2	1
Word	The size of the heading is large and the text has rich decoration	The size of the heading is not large and the text has some decoration	The size of the heading is too small and the text has no decoration
Space	The distribution of the space is fine	The distribution of the space is not good enough	The distribution of the space is messy
Color	The product is colorful and the color is appropriate	The product only contains two colors	The product is boring
Theme	The content of the product is consistent with the theme	Part of the content is consistent with the theme	The content of the product is not relevant to the theme

10.4 Results

10.4.1 Analysis of Learning Attitude

The mean values and standard deviations of learning attitude scores for the pre-test were 3.81 and 0.72, and 4.00 and 0.65 for the post-test. The paired-sample t-test indicated that there was significant difference between the pre-test and post-test ($t = 3.27$, $p < 0.01$). This finding revealed that students' learning attitude improved after collaborative inquiry learning.

10.4.2 Analysis of Interaction Patterns

In order to analyze interaction patterns of all the participants, social network analysis was performed by Gaphi. In this study, the degree centrality, betweenness centrality, and closeness centrality were calculated by Gaphi. Degree centrality represents the number of connections one node has with other nodes (Newman 2010; Resendes et al. 2015). Applying this to the study, degree centrality indicated the popularity or centrality of learners. Betweenness centrality measures the degree of connectivity of a node (Newman 2010; Resendes et al. 2015). In this study, betweenness centrality represented the extent to which a learner was connected within the network. Closeness centrality represents the proximity of one node to all other nodes (Newman 2010; Resendes et al. 2015). In this study, closeness centrality revealed how closely connected learners are to each other.

Figure 10.1 shows the result for degree centrality. It can be clearly seen that teacher 1 was the most popular with the highest centrality in the whole network, followed by the teacher 2, student zyw, and then student zmy. Figure 10.2 shows the result of betweenness centrality. The findings show that teacher 1 was highly connected within the network and bridged the most social clusters, followed by students cfy and lyh. Figure 10.3 shows the result of closeness centrality. The findings revealed that student yll had the highest proximity in the whole network, followed by teacher 2, and students hch and mjq.

10.4.3 Analysis of Knowledge Advancement

In order to analyze the level of knowledge advancement, both the scienficness and complexity of knowledge building were analyzed based on the coding scheme (see Table 10.1). Table 10.3 presents the results of knowledge advancement.

With respect to scientificness, the result indicated that 0.4 % of the discussion transcripts were pre-scientific, 1 % were hybrid, 18.6 % were basically scientific,

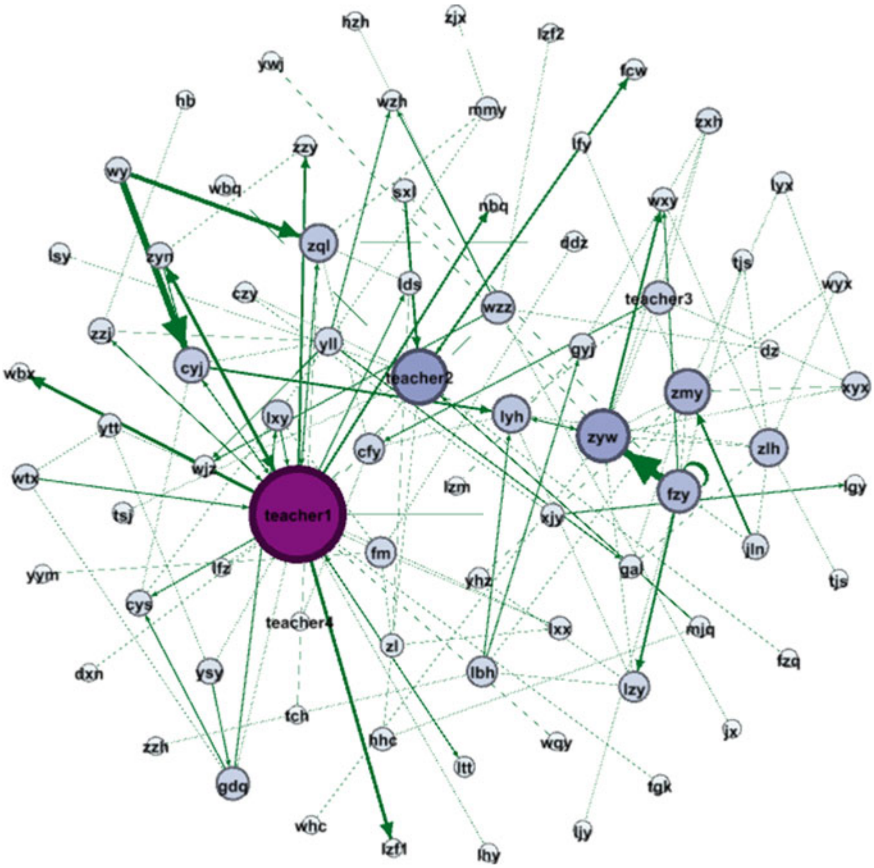

Fig. 10.1 The result of degree centrality

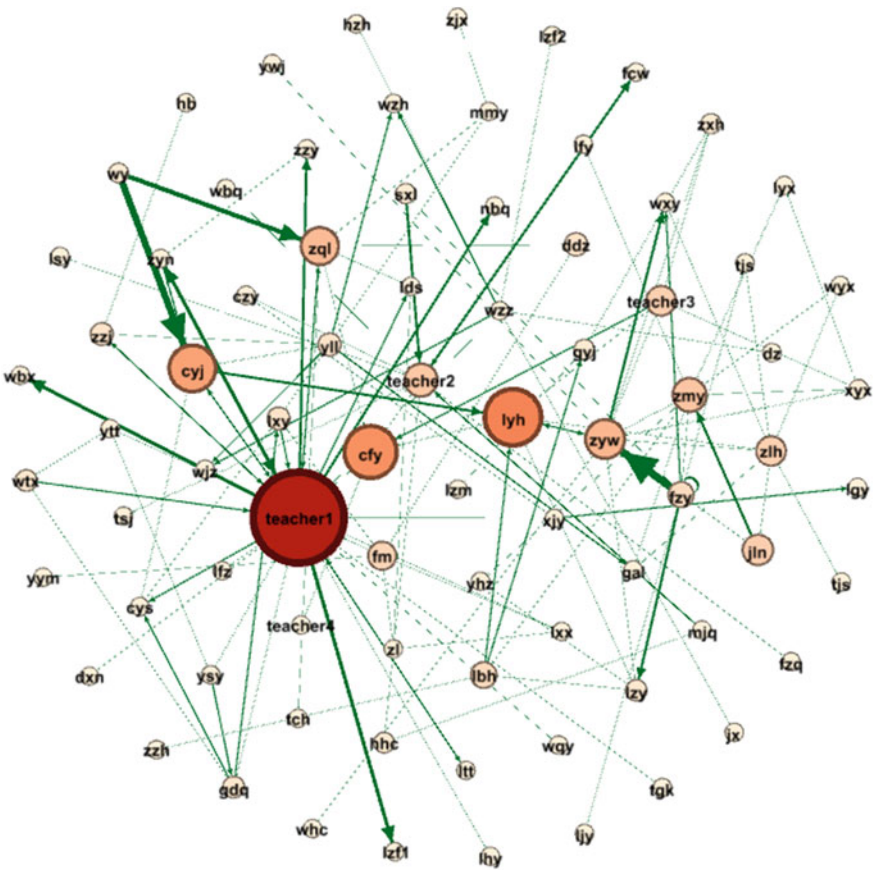

Fig. 10.2 The result of betweenness centrality

and 64 % were scientific. The remainder were not related to the topic. This finding revealed that most learners had acquired scientific knowledge about tools in daily life.

With regard to complexity, the result demonstrated that 16 % of the discourse transcripts were unelaborated facts, 67.3 % of them were elaborated facts, only 0.9 % of them were unelaborated explanations, and 15 % of them were elaborated explanations. The remainder were not relevant to the subject matter. This finding indicated that most learners could elaborate terms, phenomena, and facts. However, only few of the students could provide elaborated explanations about tools in daily life. Therefore, the teachers should provide more elaborated explanations to deepen their understanding about tools in daily life.

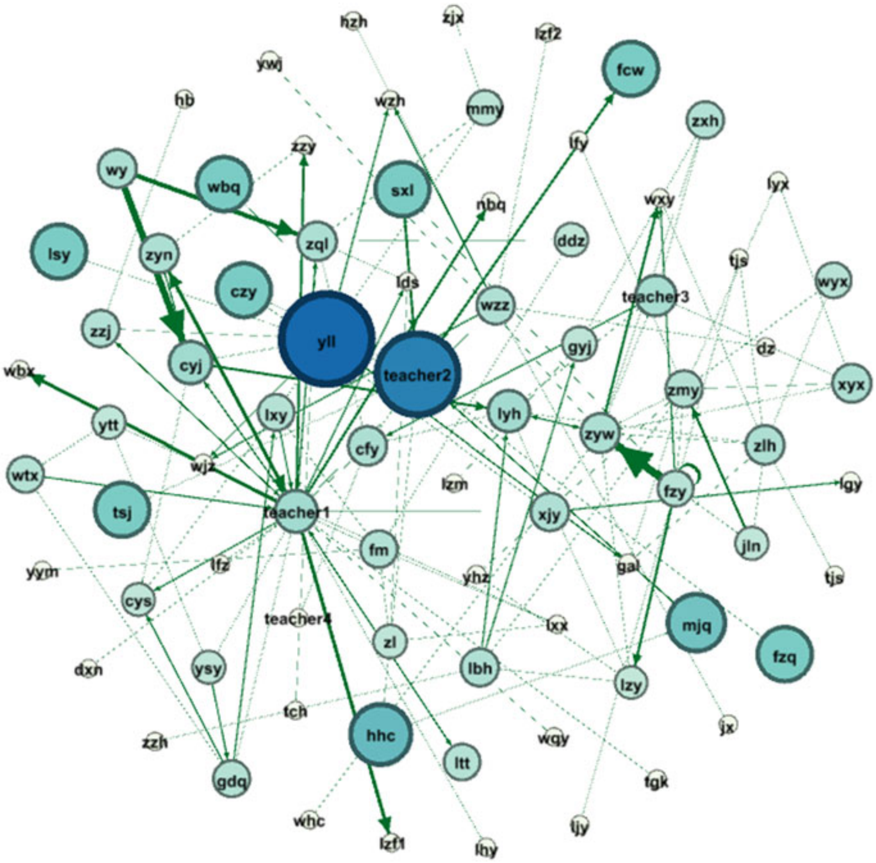

Fig. 10.3 The result of closeness centrality

Table 10.3 The results of knowledge advancement

Code		Percentage (%)
Scientificness	Pre-scientific	0.4
	Hybrid	1
	Basically scientific	18.6
	Scientific	64
	Others	16
Complexity	Unelaborated facts	16
	Elaborated facts	67.3
	Unelaborated explanations	0.9
	Elaborated explanations	15
	Others	0.8

10.4.4 Analysis of Group Products

In order to analyze the quality of the final group products, two raters evaluated 48 group products according to set criteria (as shown in Table 10.4). The results indicated that the means and standard deviations of group products were 8 and 2.15, respectively. Overall, all of the groups made great efforts to collaboratively draw the artifacts. The subsequent figures show part of the artifacts. Figure 10.4 shows one of the products about Chinese brushes, Fig. 10.5 shows one of products about chopsticks, and Fig. 10.6 shows one of products about bicycles.

10.5 Discussion

This study examined learning attitudes and group products after collaborative inquiry learning. The result indicated that learning attitude improved after collaborative inquiry learning. The main reason for that was collaborative inquiry learning promoted students to be more willing to learning. The result also revealed that the overall quality of group products was high with every group making an artifact about tools in daily life.

In order to examine the interaction patterns, the degree centrality, closeness centrality, and betweenness centrality were analyzed by Gaphi. The findings also demonstrated that the two teachers in Fuquan elementary schools had the highest centrality. Therefore, these teachers made great efforts to guide and monitor the collaborative inquiry learning processes. Constructivistic theories posit that teachers should be mentors or moderators of learning (Collins 2006). Urhahne et al. (2010) also proposed that teachers should envision the lesson, enable collaboration, encourage learners, ensure learning, and evaluate achievement during the collaborative inquiry learning process. Therefore, teachers played a very crucial role in achieving successful and productive collaborative inquiry learning.

With respect to the level of knowledge advancement, the finding indicated that the discourse of most learners was scientific. However, most learners could not provide elaborated explanations about tools in daily life. They could only provide elaborated facts during online discussions. This finding revealed that most learners did not get a deep understanding of the selected tool. Nevertheless, many studies have reported the value of generating explanations (Aleven and Koedinger 2002; Chi et al. 1994). Self-explanations can help learners apply their beliefs and prior knowledge to get a better understanding of new knowledge and experiences (Lombrozo 2012). Previous studies have also indicated that the most effective learners generated more frequent and powerful self-explanations while learning (Wong et al. 2002). Therefore, providing elaborated explanations was very helpful to improving learning performance. Students should initiate explanations themselves in order to deepen their understanding of a subject matter.

Table 10.4 The score for 48 group products

No.	Word	Space	Color	Theme	Total
1	2	3	3	2	10
2	1	1	1	2	5
3	2	1	1	2	6
4	2	2	3	3	10
5	2	2	3	2	9
6	2	3	3	3	11
7	2	3	3	3	11
8	1	2	2	2	7
9	1	1	2	2	6
10	2	2	2	3	9
11	2	3	3	3	11
12	1	1	2	3	7
13	3	2	2	3	10
14	2	1	1	3	7
15	2	2	2	3	9
16	2	2	2	3	9
17	1	1	1	2	5
18	1	2	3	3	9
19	2	2	1	2	7
20	1	1	3	1	6
21	1	3	2	2	8
22	2	1	1	2	6
23	2	3	3	3	11
24	3	2	2	3	10
25	3	3	2	3	11
26	2	2	2	2	8
27	1	2	1	3	7
28	1	2	2	3	8
29	1	2	2	3	8
30	1	1	1	3	6
31	3	2	2	1	8
32	2	2	2	1	7
33	1	1	2	1	5
34	3	3	2	1	9
35	2	3	2	3	10
36	1	1	1	1	4
37	1	2	2	3	8
38	1	1	1	1	4
39	1	1	1	2	5
40	3	3	1	3	10
41	3	2	1	3	9

(continued)

Table 10.4 (continued)

No.	Word	Space	Color	Theme	Total
42	2	2	2	3	9
43	3	2	1	3	9
44	3	3	2	3	11
45	2	2	2	1	7
46	2	2	1	1	6
47	1	1	1	1	4
48	3	3	3	3	12

Fig. 10.4 The group product about Chinese brushes

This study has several implications for teachers and practitioners. First, collaborative inquiry learning is a very effective strategy to improve learning attitudes toward science. Learners become more interested in science by actively preparing for courses, proposing questions, and finding solutions. They can overcome various kinds of difficulties encountered during collaborative inquiry learning. Second, teachers play a central role in implementing collaborative inquiry learning. Teachers can facilitate collaborative inquiry learning by answering questions, providing elaborated explanations, making comments, and reminding students to complete tasks. As a facilitator, teachers should intervene when off-topic discussion occurs. As a mentor, teachers should provide just-in-time feedback for students otherwise they may become confused or frustrated. Third, collaborative knowledge building is a crucial task for collaborative inquiry learning. All of the participants in

Fig. 10.5 The group product about chopsticks

Fig. 10.6 The group product about bicycles

the study shared the responsibility of advancing the community's knowledge and making contributions to knowledge building (Zhang et al. 2011). However, this point was not recognized by most students during collaborative inquiry learning. Some of them were more active in posting their ideas, while others did not share information or post ideas. Therefore, training about how to conduct collaborative knowledge building is essential so as to advance community knowledge.

This study has several limitations. First, this study did not include a control group to compare the effectiveness of collaborative inquiry learning. Therefore, caution should be taken when applying the findings of this study. Future studies will include a control group to examine the effectiveness of collaborative inquiry learning. Second, only one task was conducted in collaborative inquiry learning. Future studies will explore the influence of different kinds of task on learning attitude, interaction patterns, and knowledge advancement.

10.6 Conclusion

This study investigated learning attitudes toward science, group products, interaction patterns, and the level of knowledge advancement in collaborative inquiry learning. The results demonstrated that learners had positive attitudes toward science after collaborative inquiry learning. Overall, the group products were satisfied and of high quality. In addition, the interaction pattern was characterized as teacher centered during collaborative inquiry learning processes. Although the discourse was scientific, only a few students provided elaborated explanations. A deep understanding about tools in daily life still remained lacking. Furthermore, collective knowledge still needs to be advanced by each member. Therefore, every member shared the responsibility to construct knowledge for the community. All in all, collaborative inquiry learning was very effective in engaging students in learning as well as improving students' attitudes toward science and level of knowledge advancement.

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