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The effect of interaction between knowledge map and collaborative learning strategies on teachers' learning performance and self-efficacy of group learning

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ABSTRACT

In this study, an integrated collaborative learning and knowledge map approach was developed for online teacher professional development. An online teacher education environment based on that approach was constructed. To investigate the interaction between the knowledge map and collaborative learning strategies on teachers' learning performance and self-efficacy of group learning, a 2 × 2 experiment was acted out. The study subjects were 179 in-service teachers from primary schools in China. The participants were divided into four groups to learn theories and cases of educational research methods using different online learning strategies (individual learning or collaborative learning) and knowledge map strategies (using a knowledge map or not). The results revealed two notable findings. First, both the knowledge map and collaborative learning strategies were significantly conducive to enhance the teachers' learning performance. Second, the interaction between the two kinds of strategies showed that the knowledge map strategy was potential to promote the self-efficacy of group learning among teachers who used the collaborative learning strategy. Thus, we conclude that the collaborative construction of group knowledge map could be an effective approach to promote teachers' knowledge construction and provide visual interaction support for teachers' online professional development.

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KEYWORDS
Knowledge map; collaborative learning; teacher professional development; collaborative construction; self-efficacy of group learning

1. Introduction

Education today faces various complex challenges – from strict academic standards and objectives to incorporating new pedagogical knowledge into the classroom. In many countries, teacher professional development is widely regarded as a key method for tackling such problems and improving the quality of education (Depaepe & König, 2018; Ma, Xin, & Du, 2018). Many approaches and strategies are being employed to improve the quality of teacher education, such as inviting experts to introduce knowledge or guide practical training face-to-face. (Zhou, Guo, & Zhou, 2015). With technological advances, new and different forms of education for teachers have emerged. Among them, online teacher professional development has won wide interest. Online teacher professional development is not limited by time and space; it offers opportunities for self-generating and on-demand learning (Prestridge, 2017).

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Many researchers have, however, reported that without effective guidance or support, online teacher professional development may have a negative influence on training (Biasutti & El-Deghaidy, 2015). For example, Bawa (2016) determined that confusion with knowledge structure, and difficulty in constructing knowledge are major factors in hindering the effect of online learning. Appropriate learning supports are needed to help learners form structured knowledge and hold discussions based on what they are learning (Sung & Hwang, 2013).

It is widely acknowledged that knowledge map can facilitate connecting new knowledge with existing knowledge structures and provide users with effective navigation (Zhong et al., 2015). Specifically, knowledge map can reveal distributions and relationships among knowledge in a clear, dynamic way (Ho et al., 2018); they simplify the relational complexity of structured information and knowledge (Shaw, 2019). Knowledge map is a potential strategy in improving online teacher professional development.

Meanwhile, the loneliness and inadaptation to independent learning could negatively affect the effect of online learning (Bawa, 2016). Through survey research, Parsons et al. (2019) found that most teachers have low self-efficacy of group learning in online courses. For higher efficacy, proper support and effective learning strategies are necessary to achieve effective online teacher professional development.

Several researchers have found that collaborative learning can be viewed as an important strategy for solving problems in online teacher professional development (Biasutti, 2011). Collaborative learning has the potential for facilitating knowledge gains (Stahl, 2011) and promoting cognitive development (Gu & Cai, 2019). Learners in a collaborative environment need to integrate multiple perspectives, provide rich feedback and insights to one another, and engage in reflections through focused peer discussions; in that way, learners can develop relationships with others online, expand their professional networks, and foster learning (Luo et al., 2017). Many researchers have indicated the benefit of collaborative learning in promoting peer interactions (Charitonos et al., 2012).

The present study integrates the ‘‘knowledge map’’ and ‘‘collaborative learning’’ strategies, and builds a new learning approach named collaborative construction of group knowledge map, aiming to improve the quality of online teacher education. We conducted a 2×2 experiment to investigate the effects of knowledge map and collaborative learning strategies (and interactions between the two kinds of strategies) on in-service teacher learning performance and self-efficacy of group learning. Different groups of participants adopted different learning strategies (individual learning or collaborative learning) and knowledge map strategies (using a knowledge map or not). Two research questions are posed to evaluate the effectiveness of the proposed approach:

1. In online training, can the collaborative construction of group knowledge map promote the learning performance of learners?
2. In online training, can the collaborative construction of group knowledge map promote the self-efficacy of group learning of learners?

2. Literature review

2.1. Online teacher professional development

To meet the demands of social development and knowledge growth, teachers need ongoing professional development (van den Bergh, Ros, & Beijaard, 2015). Professional development refers to the process of learning and keeping up to date in one's area of expertise – both for personal development and career advancement. People who engage in professional development are interested in increasing their own skills or knowledge, enhancing their ability to do their work, and developing lifelong learning (Vu et al., 2014). Some surveys, e.g. Holmes (2013), have revealed that professional development could afford teachers the opportunity to solve teaching problems, develop reflections, and improve their performance.

Online training could be a convenient, flexible approach for teacher professional development, it enables teachers to acquire constant support, participate in learning activities, and interact and communicate with colleagues (Liu et al., 2018). Although studies have found the degree of user satisfaction for teacher online professional development courses to be relatively high, many problems remain to be solved. For example, some research has reported the deficiencies of online teacher professional development, including the lack of teacher buy-in and community support as well as participation attrition (Giles & Hargeaves, 2006). Meanwhile, Bawa (2016) determined that confusion with knowledge structure, and difficulty in constructing knowledge are major factors in hindering the effect of learning. Thus, it is crucial to develop proper approaches for promoting effective implementation and growth of online teacher professional development.

2.2. Collaborative learning and collaborative knowledge construction

Collaborative learning can be regarded as learners in a structured group working together, helping one another, and contributing their abilities to achieve a certain shared learning target (Jones, Antonenko, & Greenwood, 2012). With the growth of mobile communication technology and the Internet, teachers can learn and participate in online training in an information technology environment based on collaborative knowledge construction. Gentile et al. (2007) argued that knowledge acquisition is not a transfer from teachers to learners: it is the result of collaborative activities. Especially in a mobile learning environment, collaborative learning is of great significance. For example, regarding knowledge construction, Hong and Lin (2019) adopted mixed research methods; they found that online collaborative knowledge construction activities were conducive to learners' effective collective knowledge formation and innovative ability cultivation. Similarly, Gutiérrez-Braojos and Salmerón-Pérez (2015) conducted a survey on a collaborative knowledge construction community for learners of social science degree courses in 72 universities; they found that a properly designed, well-managed online learning environment was conducive to developing students' collective cognitive ability.

Harasim (1989) discussed the process of collaborative knowledge construction. According to Harasim, the process includes discussing views together, evaluating one another, testing and argumentation, questioning one another, and synthesizing different views through consultation. With the developing concept of personalized learning, Bereiter and Scardamalia (2003) defined the concept of collaborative knowledge construction as generation, sharing knowledge and personal knowledge, and correcting the public's cognitive process; thereby, learners create a common vision, negotiate, discuss, share understanding, build consensus, and ultimately create artifacts. Consequently, it is evident that collaborative knowledge construction today concerns both the construction of group knowledge and knowledge construction of individuals in groups.

A number of paradigms exist for collaborative knowledge construction. According to Gunawardena (1997), collaborative knowledge construction is an active knowledge construction process for learners. In the process of construction and exploration, learners negotiate, evaluate, reflect, apply, and reach a consensus. The result is optimizing problems to be explored and constructing better knowledge.

The concept of collaborative knowledge construction has gradually influenced teacher training. Chen et al. (2017) pointed out that the collaborative knowledge construction offers considerable benefits for teachers to obtain a deeper understanding of information and develop learning autonomy and teaching skills.

2.3. Knowledge map and collaborative construction of group knowledge map

According to O'Donnell, knowledge refers to the objective knowledge of human beings, and the knowledge structure can be drawn into the knowledge of each unit as a node (O'Donnell, Dansereau, & Hall, 2002). A knowledge map involves utilizing the knowledge network to explain the process

of cognition change and promote an understanding of knowledge (O'Donnell, Dansereau, & Hall, 2002). A knowledge map organizes scattered knowledge artifacts and presents them visually in meaningful categorizations; that can efficiently and effectively promote users to browse, navigate, and understand knowledge artifacts in a large knowledge space (Lv, Zhao, & Yu, 2016).

Recent research has illustrated the merits and effectiveness of knowledge map. For example, Balaid et al. (2016) presented a summary of the main benefits of such maps: "to connect experts"; "accessing knowledge in time"; "identifying knowledge assets"; "identifying knowledge flow"; "identifying existing knowledge resources"; "organizational restructure"; "identifying knowledge gaps"; "team building"; and "identifying untapped knowledge." Similarly, Ho et al. (2018) found the following with knowledge maps: they stimulated students' creativity; improved and motivated learning; helped students identify important concepts; were simple to use; helped link matters; and allowed students to see the overall picture, share ideas, and improve understanding.

The approach of collaborative construction of group knowledge map can help solve problems by visually documenting each learner's contribution to group comprehension: knowledge maps can increase communication and share common practices among group members (Balaid et al., 2016). As noted by O'Donnell et al. (2002), knowledge maps can be used as scaffolding for cognitive processes to help make decisions in collaborative learning. For example, Liu et al. (2010) demonstrated that knowledge maps can facilitate the creation of shared understanding, reduce misunderstanding among individuals, and promote the tendency for collaborative learning. Thus, in collaborative construction of group knowledge map, learners can promote their thinking ability through interaction, summarizing texts, and identifying key phrases in a systematic manner.

This paper integrates the "knowledge map" and "collaborative learning" strategies, builds a new learning approach named collaborative construction of group knowledge map. It investigates the effect of interaction between collaborative learning and knowledge map strategies on the online teacher professional development.

3. The online learning environment for collaborative construction of group knowledge map

The knowledge map tool used in this study was based on the Learning Cell Platform (http://lcell.bnu.edu.cn). The tool is an embedded function of that platform: it can provide support for teachers in constructing group and individual knowledge maps; it can also present the process and results of teachers' knowledge construction in real time and be used for a visual presentation. The tool can also support teacher voting and discussing about group knowledge map, thereby promoting cognitive interaction and the development of group knowledge maps. The specific functions are as follows.

3.1. Constructing an individual knowledge map

At the interface of the personal knowledge map, teachers can independently create knowledge nodes; they can choose relationships among nodes, describe nodes and associated resources. To be more specific, learners can describe the knowledge node by themselves. After a knowledge node has been created, teachers can associate a corresponding resource for any knowledge node on the map. All resources created by the teachers are presented in a list. They can also choose the relationship between knowledge nodes, as shown in Figure 1. Among knowledge nodes, the relationship includes similarity, converse, correlation, equivalence, preorder, successor, upper concept, lower concept, inclusion, and belonging. At the same time, learners can describe the knowledge nodes, including characteristics, scope and application. As a result, the knowledge nodes and their relationships constructed by learners can be visualized on the knowledge map in real time.

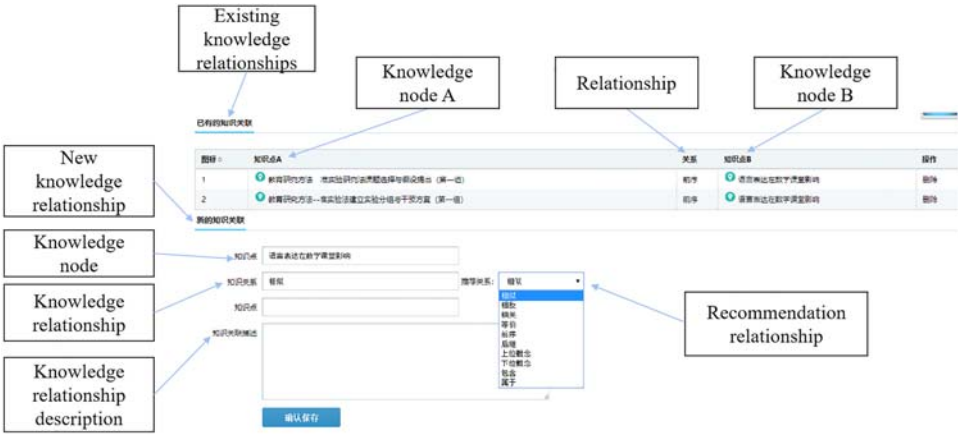

Figure 1. The selection interface for constructing knowledge relationship.

3.2. Constructing group knowledge map

As for constructing group knowledge map, teachers in the same online learning group can build a knowledge map together with their group members. Trainees can create a common group knowledge map based on collaborative learning; that includes collaboratively creating knowledge nodes and their relationships, describing nodes, and adding associated resources. Figure 2 shows the interface for the development of a group knowledge map. Nodes added by a single teacher are not necessarily valid or recognized. Thus, in the "Knowledge description" section, other teachers in the same group can vote for nodes; if the approval rate of the knowledge node is less than 60%, the node becomes modified or deleted.

Teachers can enter a discussion through the "Discuss" button: there, they can make an in-depth discussion about each node as shown in Figure 3. Thereafter, the interface for developing a group knowledge map indicates whether or not the node has developed.

Figure 2. Interface for developing a group knowledge map.

Figure 3. The discussion interface for "Group knowledge map".

4. Methodology

Based on the above online learning environment for collaborative construction of group knowledge map, a quasi-experimental design was conducted involving in-service teachers. The effects of the approach on teachers' learning performance and self-efficacy of group learning was investigated after 4 weeks online learning.

4.1. Participants

The participants of the study were 179 in-service teachers recruited from China. They are mostly math, Chinese and English teachers, teaching students in grade 3rd through 6th. All participants had an undergraduate or graduate degrees and 5–10 years of teaching experience. Beside, all participants have rich experience in online teacher training.

The content of course was about the methods and cases related to an educational research method – quasi experimental method. All of the participants learned using the same instructional videos and learning guidance. At the beginning of the experiment, a questionnaire about the in-service teachers' basic information, such as their age, number of years teaching, grade that they teach, and experience of online learning was conducted. Every teacher was asked to fill out the pre-test reflecting their level of the specific knowledge and ability. According to the scores of the pre-test, the participants were divided into 4 groups at the same initial level. Using purposive sampling, we randomly selected one group as the experimental group and the others as the control groups. K-C (Knowledge map-Collaborative learning) group was experimental group (n = 44); K-I (Knowledge map-Individual learning) was control group 1 (n = 45); N–C (Non-knowledge map-Collaborative learning) was control group 2 (n = 44); and N-I (Non-knowledge map-Individual learning) was the control group 3 (n = 46). Table 1 clarifies how the groups were treated.

Table 1. Treatment of the four study groups.

	Collaborative learning	Individual learning
Knowledge map	K-C group (experimental group): knowledge map and collaborative learning	K-I group (control group 1): knowledge map and individual learning
Non-knowledge map	N-C group (control group 2): non-knowledge map and collaborative learning	N-I group (control group 3): non-knowledge map and individual learning

Table 2. The questionnaire about self-efficacy of group learning.

	Description:
1	I would like to give feedback to them after reading my homework or report.
2	I could put forward a comprehensive viewpoint based on the ideas or knowledge of the teachers.
3	I could accept other teachers' opinions and take their suggestions constructively.
4	I would like to help other teachers improve their ideas or knowledge.
5	I could explain my ideas openly to other teachers.
6	When I didn't understand other teachers, I asked them to explain more clearly.
7	I could organize teachers (e.g. division of tasks) to jointly complete the assigned tasks within a specified time.

4.2. Instruments

The measurement instruments adopted in this study were pre- and post-test about the knowledge and ability about educational research method, and a questionnaire about self-efficacy of group learning.

The pre- and post-test were developed by three experts. The reliability and validity of the test paper were consistent with the difficulty coefficient of the test paper. Both tests were designed to assess learners' knowledge and ability about educational research method, and comprised eight one-choice question items, four true-false items, and four open question-and-answer items. The total score of each test was 100. In the pre-test and post-test, the multiple choice questions and the right and wrong judgment questions were automatically judged and given by the system. The four open question-and-answer items were scored by three educational technology experts, and the average scores would be taken as the final scores.

A questionnaire about self-efficacy of group learning developed by Hwang, Shi, & Chu (2011) was adopted in this research. The questionaire comprised seven items using a five-point Likert scale. This questionnaire assessed the teachers' self-efficacy of group learning. Cronbach's alpha for the questionnaire was greater than 0.85, indicating that the questionnaire was reliable. Self-efficacy is people's confidence in their ability to achieve specified goals or performance, and it is one of the most important motivators of effort, perseverance and learning motivation (Bandura, 1997;Pintrich & Schunk, 2002). This questionnaire has been confirmed to be able to explore the willingness and motivation of the students to participate in learning activities (Hwang, Wu, & Ke, 2011) (Table 2).

4.3. Experimental procedure

Figure 4 shows the 4-week experimental procedure. At the beginning of the experiment, all teachers in the four groups took the pre-test about the educational research method and the pre-questionnaire about self-efficacy of group learning. In the 1st week, the organizer introduced the syllabus and learning goals. Subsequently, the participants in the K-C group learned the online course and applied knowledge map and collaborative learning strategies during their learning process. They could use knowledge map to dynamically present knowledge structures and exchange learning materials and learning experiences in 4–5 persons' groups. The participants in control group 1 could build knowledge maps on their own according to the contents that they learned. The participants in control group 2 could submit their learning notes in 4–5 persons' group discussion areas and exchange learning materials. The participants in the control group 3 could watch the videos and learn the materials individually and submit the learning notes after learning the course. All the participants in the 4 groups could get the same learning contents and materials. Also, they could post questions and share information in the public discussion areas for each group. After the 4th week, all the participants took the post-test about the learning performance and post-questionnaire about self-efficacy of group learning.

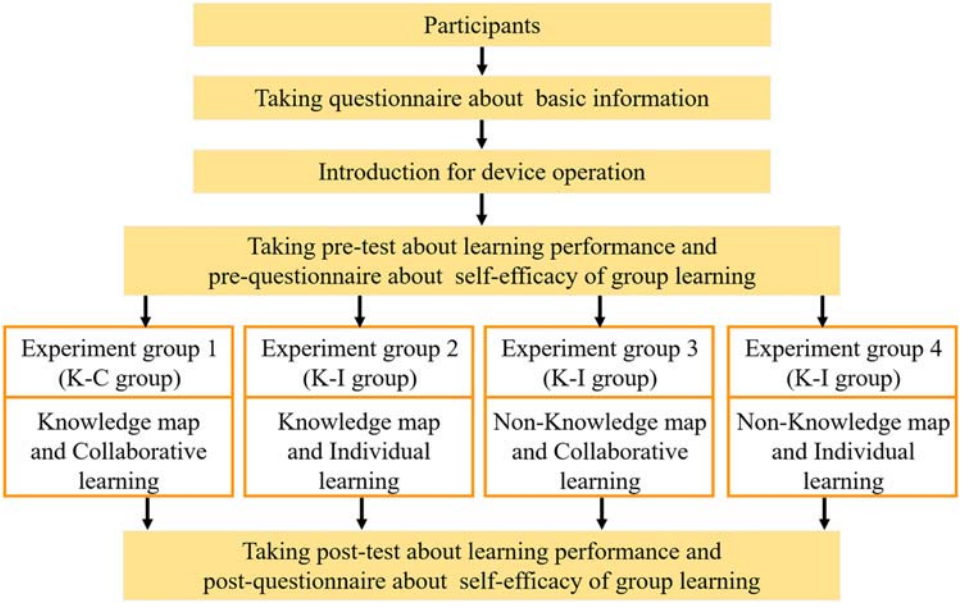

Figure 4. Experiment design.

5. Results

In this study, we adopted knowledge map and collaborative learning strategies to support the learners, who were in-service teachers taking an online learning course. We conducted a quasi-experiment to investigate the effects of those approaches on the teachers' learning performance and self-efficacy of group learning.

5.1. Analysis of learning performance

The descriptive data of the learning performance for the four groups appear in Table 3. We undertook a one-way analysis of variance (ANOVA) on the pre-test: no significant differences emerged among the four groups ($F = 0.55$, $p = 0.459 > .05$). This finding indicates equivalent prior knowledge among the teachers in the four groups before engaging in the learning activities. To examine the effectiveness of our approaches, we employed a two-way analysis of covariance (ANCOVA) using the pre-test scores as the covariates; we used the knowledge map strategy (divided into the knowledge map and non-knowledge map strategies) and the collaborative learning strategy (divided into

Table 3. Descriptive data of the learning performance of the four groups.

Source		Pre-test		Post-test		
Knowledge map	Collaborative learning	M	SD	M (adjusted M)	SD	n
Knowledge map	Collaborative learning	58.09	11.58	78.45	11.72	44
	Individual learning	58.18	11.93	67.76	8.50	45
	Total	58.13	11.69	73.04	11.50	89
Non-Knowledge map	Collaborative learning	55.57	9.77	69.61	11.62	44
	Individual learning	57.67	10.54	61.37	8.95	46
	Total	56.64	10.17	65.40	11.09	90
Total	Collaborative learning	56.83	10.73	74.03	12.43	88
	Individual learning	57.92	11.19	64.53	9.26	91
	Total	57.39	10.95	69.20	11.90	179

M, mean; SD, standard deviation; n, number of participants.

Table 4. Results of two-way ANCOVA on teacher learning performance.

Source	SS	df	MS	*F*	*η2*
Pre-test(covariate)	3694.65	1	3694.65	44.28***	.208
Knowledge map	1928.47	1	1928.47	23.11***	.120
Collaborative learning	4427.54	1	4427.54	53.07***	.239
Knowledge map*Collaborative learning	8.80	1	8.80	0.11	.001
Error	14100.35	169	83.43		

SS, sum of squares of deviation from mean; df, degree of freedom; MS, mean square; *F*, F-test; η^2, effect size; Knowledge map* Collaborative learning, interaction between knowledge map strategy and collaborative learning strategy; ***p<.001.

collaborative learning and individual learning strategies) as independent variables; we adopted the post-test scores as the dependent variables. ANCOVA excludes the part attributed to the differences in the knowledge base of the subjects in the total variation of learning performance, so as to facilitate the exact analysis of the effect of the two kinds of strategies on teachers' learning performance.

As the assumption of homogeneity of regression was not violated ($F = 0.55$, $p = 0.459 > .05$), we could have a two-way ANCOVA on learners' learning performance, and the results appear in Table 4. It is evident that the interaction effect between knowledge map strategy and the collaborative learning strategies was not significant ($F = 0.11$, $p = 0.74 > .05$). It was necessary to directly examine the main effects of the two independent variables. Significant effects were confirmed for the knowledge map strategy ($F = 23.11$, p = 0.000 < .001, $\eta2 = 0.120$) and for the collaborative learning strategy ($F = 53.067$, $p = 0.000 < .001$, $\eta2 = 0.239$) on learners' learning performance. Using the data in Table 3 and the visual presentation in Figure 5, we found that teachers who used knowledge maps attained better learning performance (K-C and K-I groups, adjusted mean = 73.04; standard deviation [SD] =11.69) than those who did not use them (N–C and N-I groups, adjusted mean = 65.40; SD = 11.09). Teachers who used collaborative learning (K-C and N–C groups, adjusted mean = 74.03; SD = 12.43) performed better than those who adopted individual learning (K-I and N-I groups, adjusted mean = 64.53; SD = 9.26) in learning performance.

In addition, the effect size ($\eta2$) refers to the quantity or magnitude of the effect or result expected to occur in the group, that is, the quantity or magnitude of the effect of knowledge map strategy and collaborative learning strategy on improving learners' learning performance. Using the definition proposed by Cohen (1988), we calculated the effect size ($\eta2$) of the ANCOVA results of the knowledge map and collaborative learning approaches. The knowledge map strategy represented a moderate effect size ($\eta2 = 0.120 > 0.059$) and the collaborative learning strategy represented a large effect size ($\eta2 = 0.239 > 0.138$). Thus, both knowledge map strategy and collaborative learning strategy have a positive correlation with the improvement of learning performance, the latter is stronger.

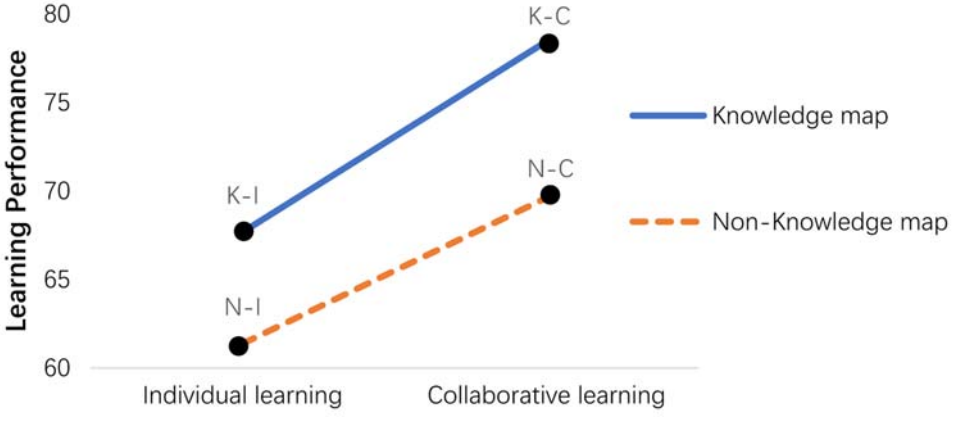

Figure 5. Effect of knowledge map and collaborative learning strategies on teachers' learning performance.

5.2. Self-efficacy of group learning

To examine the impact of different strategies on the confidence and willingness of the teachers to communicate and collaborate, this study used a two-way ANCOVA to measure the self-efficacy of group learning of the four groups. We used their pre-test scores as covariates, the knowledge map and collaborative learning strategies as independent variables, and the post-test scores as dependent variables. The descriptive data of the adjusted post-test scores on the self-efficacy of group learning in the four groups appear in Table 5.

We tested the regression homogeneity hypothesis of the learning motivation scores of the four teacher groups, and the result showed no violation ($F = 1.24$, $p = 0.268 > .05$); this finding confirmed that the 4 groups have the same variance of population and the ANCOVA test could be performed. As shown in Table 6, the ANCOVA results indicate a significant interaction effect between the independent variables ($F = 4.49$, $p = 0.036 < .05$, $\eta 2 = 0.040$) on learners' self-efficacy of group learning. It indicated that the effects of the two factors in this study are not independent, implying that the knowledge map strategy and collaborative learning strategy could influence each other's effects on the self-efficacy of group learning. Thus, we conducted a simple main effect analysis to clarify what influenced the teachers' self-efficacy of group learning. Those results appear in Table 7.

Regarding the influence of the knowledge map strategy, there was a significant difference in whether the knowledge map was used for collaborative learning ($F = 5.712$, $p = 0.019 < .05$, $\eta 2 = 0.050$); no significant difference was found in whether the knowledge map was used for individual learning. Thus, the self-efficacy of group learning in the K-C group (using knowledge map and collaborative learning, adjusted mean = 4.62; SD = 0.84) was significantly higher than in the N–C group (not using knowledge map and collaborative learning, adjusted mean = 4.06; SD = 0.82). This shows

Table 5. Descriptive data of the self-efficacy of group learning divided by knowledge map strategy.

		Pre-test		Post-test		
Knowledge map	Collaborative learning	M	SD	M (adjusted M)	SD	n
Knowledge map	Collaborative learning	3.92	0.73	4.62	0.64	44
	Individual learning	3.94	0.69	4.15	0.67	45
Non-Knowledge map	Collaborative learning	3.82	0.60	4.06	0.75	44
	Individual learning	3.89	0.78	4.25	0.81	46

M, mean; SD, standard deviation; Adjusted mean: Outliers present in data sets was removed in order to determine the adjusted mean because they could have a large impact on the calculated means of the small populations. The adjusted mean was determined by removing these outlier figures through regression analysis; n, number of participants.

Table 6. Results of two-way ANCOVA on the teachers' self-efficacy of group learning.

Source	SS	df	MS	*F*	*η2*
Knowledge map	0.56	1	0.82	0.82	0.008
Collaborative learning	1.45	1	2.12	2.12	0.019
Knowledge map*Collaborative learning	3.07	1	4.49	4.49*	0.040
Error	73.81	108	0.68		

SS, sum of squares of deviation from mean; df, degree of freedom; MS, mean square; *F*, F-test; η^2, effect size; Knowledge map* Collaborative learning, interaction between knowledge map strategy and collaborative learning strategy; *$p < .05$.

Table 7. Results of two-way ANCOVA on the teachers' self-efficacy of group learning.

Source		SS	df	MS	*F*	*η2*
Knowledge map	Collaborative learning	3.90	1	3.90	5.71*	0.050
	Individual learning	0.16	1	0.16	0.24	0.002
Collaborative learning	Knowledge map	2.75	1	2.75	4.03*	0.036
	Non-Knowledge map	0.57	1	0.57	0.84	0.008

SS, sum of squares of deviation from mean; df, degree of freedom; MS, mean square; *F*, F-test; η^2, effect size;*$p < .05$.

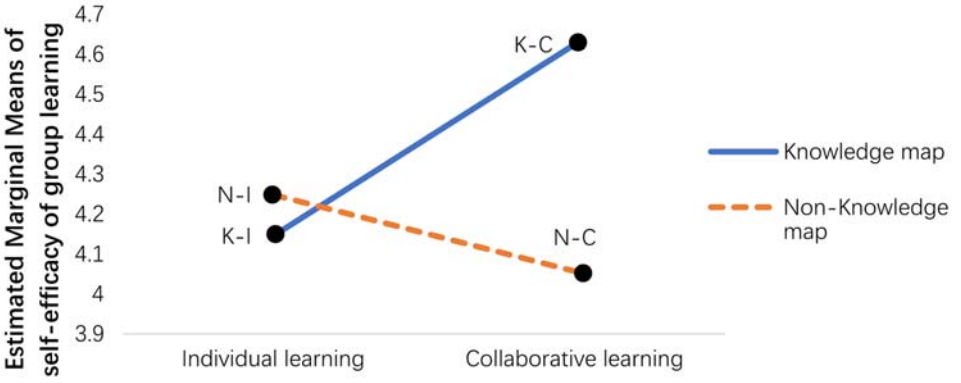

Figure 6. Interaction between knowledge map and collaborative learning strategies in the teachers' self-efficacy of group learning.

that the knowledge map method can promote the self-efficacy of group learning among online teachers through collaborative learning.

In terms of the collaborative learning strategy, we found that using knowledge map had a significant impact on the self-efficacy of group learning ($F = 4.03$, $p = 0.047 < .05$, $\eta 2 = 0.036$). We observed no significant difference between collaborative learning and individual learning in the self-efficacy of group learning when the knowledge map was not used. The self-efficacy of group learning in the K-C group (using knowledge map and collaborative learning, adjusted mean = 4.62; SD = 0.84) was significantly higher than in the K-I group (using knowledge map and individual learning, adjusted mean = 4.15; SD = 0.83).

Figure 6 presents the interaction between the knowledge map and collaborative learning strategies of the teachers' self-efficacy of group learning. Each point represents the estimated marginal means of self-efficacy of group learning of different groups. They are N-I, K-I, K-C and N–C groups. The figure indicates that when collaborative learning was adopted in the online training, teachers who used the knowledge map had significantly higher self-efficacy of group learning than those who did not. When the knowledge map was used in online training, teachers using a collaborative learning strategy achieved significantly higher self-efficacy of group learning than those employing the individual learning strategy. This finding shows that collaborative learning can effectively enhance the self-efficacy of group learning of learners using a knowledge map.

6. Discussion and conclusions

Previous research has indicated the importance of providing multimedia and proper learning guidance to support online learning (Al-Zahrani, 2015). The study integrated the "knowledge map" and "collaborative learning" strategies to build a new learning approach named collaborative construction of group knowledge map. The approach was employed in online training for teachers' professional development. We conducted an experiment on the Learning Cell platform to determine the effect of the approach. The results showed that the collaborative construction of group knowledge map significantly improved the teachers' learning performance and self-efficacy of group learning.

Regarding the teachers' learning performance, the interaction effect between the knowledge map and collaborative learning strategies was not significant; each strategy showed a significantly positive effect. This result is consistent with those of other studies, whereby concept maps (e.g. an online knowledge map, such as Mindtools) had benefits for learning performance (Hwang, Wu & Ke, 2011; Wu et al., 2012) as did collaborative learning (Huang et al., 2017). Recent studies have indicated that knowledge sharing is a strong predictor of learning performance (Eid & Al Jabri, 2016),

which may explain the above results. Collaborative learning allows learners to enhance communication; the knowledge map could be a powerful tool for learners to convert tacit knowledge into explicit knowledge, facilitating knowledge sharing and achieving knowledge convergence (Draper, 2015). Cheng and Chu (2019) integrated knowledge maps into a computer-supported collaborative learning system and found a significant improvement in student learning performance as well as a higher degree of perceived usefulness and satisfaction.

In terms of self-efficacy of group learning, this study found a significant interaction between the knowledge map and collaborative learning strategies. Self-efficacy of group learning is the learners' confidence in and expectations in their capability to successfully complete collaborative tasks in a particular domain (Hwang, Wu & Ke, 2011). Our experimental results revealed that through the collaborative learning strategy, the self-efficacy of group learning of the teachers who employed the knowledge map strategy (K-C) was significantly higher than that of those who employed the non-knowledge map strategy (N–C). Thus, in the collaborative learning activities of professional development, the process of jointly constructing knowledge map provides a good opportunity for teachers; to some extent, that compensates for problems caused by insufficient communication and collaborative learning. Therefore, knowledge map and collaborative learning strategies could enhance enthusiasm among learners to participate in group learning activities, including raising questions and giving opinions. This conclusion is in line with the views of several researchers: they have demonstrated the effectiveness of using computerized concept maps (e.g. an online knowledge map, such as Mindtools) in a collaborative learning scenario (Hwang, Wu & Ke, 2011). Our results also showed that the self-efficacy of group learning among the teachers who used the knowledge map and collaborative learning strategies (K-C) was significantly higher than that of those who employed the knowledge map and individual learning strategies (K-I). Previous studies have indicated that such results may derive from other factors, such as complexity of learning task (Kolodner, 2007). Compared with individual learning, knowledge map learning is an unfamiliar, complex task for participants in teacher professional development; however, collaborative learning can reduce learners' pressure and increase their eagerness to collaborate with peers.

In conclusion, the integrated collaborative learning and knowledge map strategies used in this study (i.e. collaborative construction of group knowledge map) could be effective in helping teachers' knowledge construction and providing visual interaction support for teachers' online professional development. We hope this paper offers important practical implications. However, there are still some limitations: we found it difficult for teachers to achieve effective growth of practical abilities after 4 weeks of online teacher education. It is suggested to extend the training time for follow-up research, or pay more attention to teachers' improvement of practical abilities. In future research, more experiments could be conducted to investigate the impact of collaborative construction of group knowledge map on teachers using different personal factors from both the cognitive and affective domains. The approach could also be applied to other online courses for teacher education; the knowledge map strategy could be adopted in conjunction with other strategies to identify a more practical approach for online teacher professional development.

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