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Fostering deeper learning in a flipped classroom: Effects of knowledge graphs versus concept maps

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Abstract

Flipped classroom is an approach that has been increasingly used in K-12 and higher education. Many studies on the flipped classroom have focused on student behaviors, with inadequate attention to student thinking, which is crucial to learning. Meanwhile, prior studies have examined the effects of visualization tools, such as concept map, on improving student learning through in-depth thinking. Another related approach is knowledge graph, which presents a set of entities and their relationships in a graph as well as in a machine language for further processing and reasoning. It has a potential to support collaborative knowledge construction by automatic combination of individual knowledge graphs. To compare the effects of knowledge graph and concept map on student learning in a flipped classroom, we conducted an experimental study in fifth grade class at an elementary school. Students in the experimental group used a knowledge graph tool in the Learning Cell System, while those in the control group used a concept map tool, XMind, to support their learning of ancient Chinese poetry. The results showed that learning with knowledge graph resulted in better performance in the breadth and depth of subject knowledge as reflected in the students' learning products (ie, concept maps or knowledge graphs).

Introduction

A flipped classroom is a popular technology-enhanced teaching and learning approach that enables effective interactions and feedback by reversing the time and stage orders of traditional teaching methods (Lai & Hwang, 2016; Lo, Chi, & Hew, 2018). Unlike traditional teacher-centered learning, the flipped classroom focuses on online teaching resources, interactive activities and learning tools to promote students' active participation (Foster & Stagl, 2018; Yilmaz, 2017). Recent research has indicated that the flipped classroom focuses more attention on students' problem-solving experiences, providing more opportunities for learning, maximizing interaction time, giving instant feedback and allowing for self-paced learning (Hao, 2016; Thai, Wever, & Valcke, 2017; Sun, Xie, & Anderman, 2018). A flipped classroom approach aids teachers and students in developing a deeper understanding of learning content.

However, the flipped classroom has traditionally placed more emphasis on watching videos and participating in activities, with less attention to the development of higher order thinking skills

Practitioner Notes

What is already known about this topic

- The flipped classroom can improve student learning by enabling active participation and interactions.
- The concept map is an effective learning tool that can foster meaningful understanding and higher order thinking in both traditional and flipped classrooms.
- The knowledge graph is a related tool that presents a set of entities and their semantic relationships in a graph as well as in a machine language to support further processing.
- The knowledge graph can support collaborative knowledge construction by automatic combination of individual knowledge graphs.

What this paper adds

- We conducted an experimental study to compare the effects of knowledge graph and concept map on student learning in a flipped classroom.
- Compared with concept map, learning with knowledge graph resulted in better performance in the breadth and depth of subject knowledge as reflected in the students' learning products (ie, concept maps or knowledge graphs).

Implications for practice and/or policy

- Learning with knowledge graph fosters more cognitive engagement in exploring the relationships between concepts represented in both individual and converged knowledge graphs.
- The converged knowledge graph offers the teacher a big picture of the entire class in student understanding.
- Relevant training should be provided to students and teachers for effective use and learning with the knowledge graph tool.

or to knowledge construction processes (O'Flaherty & Phillips, 2015; Song & Kapur, 2017). That is, students' learning in a flipped classroom is focused around active behaviors, rather than the depth of cognitive engagement.

Meanwhile, prior studies have examined the effects of visualization tools, such as concept map, on improving student learning through in-depth thinking. A concept map is a diagram that represents the relationship between concepts and propositions (Novak & Gowin, 1984), and is widely considered to be an effective tool for helping students memorize and organize knowledge as well as for promoting the development of students' higher order thinking abilities (Novak, Gowin, & Johansen, 1983). In a flipped classroom, a concept map can play three different roles: as a learning resource, as an organizational tool and as an assessment method (Bijlani, Chatterjee, & Anand, 2013). It is used to reveal concepts and their relationships, and to help students find meaning in the learning material. Another related approach is the knowledge graph, which presents a set of entities and their semantic relationships in a graph as well as in a machine language for further processing and reasoning. It can support collaborative knowledge construction by automatic combination of individual knowledge graphs. In this way, learning with knowledge graph can foster more cognitive engagement in exploring the relationships between entities represented in both individual and converged knowledge graphs.

However, in schools, knowledge graphs are used for teaching and learning, which are referred to as concept maps (Chen, Lu, Zheng, Chen, & Yang, 2018). But, in fact, concept map and knowledge graph are different tools. As potentially supporting learning tools, it is important to elucidate the effects of concept map and knowledge graph in a flipped classroom, as well as to compare the effects of the two tools. Therefore, in this study, we aimed to examine the effects of knowledge graph and concept map in a flipped classroom and compare them in fostering deeper learning.

Literature review

Concept map

The concept map is an effective learning tool. It is widely reported that the concept map can significantly improve students' learning achievement. It helps students link new knowledge and experiences with their prior knowledge through self-checking in an organizational approach (Hwang, Yang, & Wang, 2013), and researchers have indicated that the concept map prompts constructive learning, reflective ability and active interaction (Dias, Hadjileontiadou, Diniz, & Hadjileontiadis, 2017). Collaborative concept mapping is more effective in facilitating group interaction (Wang, Cheng, Chen, Mercer, & Kirschner, 2017). In a flipped classroom, it facilitates students' understanding of knowledge and structure in an organized way (Bijlani, Chatterjee, & Anand, 2013). Concept map visualizes students' level of understanding and depth of thinking (Chevron, 2014), and can be used to assess learning progress, displaying the structural nature and extent of knowledge, including even misunderstandings of knowledge (Goldsmith & Johnson, 1990; Mcclure, Sonak, & Suen, 1999).

Knowledge graph

The term 'knowledge graph' was coined by Google in 2012 and was used to perform semantic searches; it expresses knowledge using a graph structure and unambiguous denotation of entities and relationships in the graph, which can be represented in computer-based languages to support automatic processing and reasoning. The knowledge graph organizes knowledge by linking entities or concepts and representing their semantic relationships. It has been used to facilitate knowledge organization, to make the structure of knowledge more explicit, support semantic searches and answer deeper questions (Shiffrin & Börner, 2004; Yan, Wang, Cheng, Gao, & Zhou, 2018). Although it has no definitive definition, a basic common understanding has found that a knowledge graph mainly focuses on entities and their interrelations, defines possible classes and covers various domains (Paulheim, 2017).

In practice, it is applied more frequently for automatic computer reasoning. At the same time, it is gradually applied to teaching and learning in the educational domain. For students, understanding and applying the logical relationships between entities or concepts requires more cognitive engagements. Because the nodes of the knowledge graph link entity information, it can promote deeper learning within a certain domain. Moreover, due to the concealment of group information and learning processes, it is necessary to visualize the consensus content through group awareness, so as to promote active learning (Bodemer & Dehler, 2011). Leveraging the knowledge graph, teachers and students can interact with others through knowledge nodes, explore collaborations and track real-time changes (Rafols, Porter, & Leydesdorff, 2010). The optimization of individual cognitive structures and the connection of group wisdom can be oriented using the knowledge graph, and teachers can easily focus on the construction of collaborative knowledge and the concept of generative teaching (Cui, Ma, & Yu, 2018). If a teacher constructs a knowledge graph before class and then compares it with students' graphs, this enables the teacher to reflect and adjust teaching design in a timely fashion (Lu, Zeng, Zhang, Guo, & Zhang, 2016). The knowledge graph can be effectively used as an assessment tool to evaluate the process of graph construction and the accomplishment of learning goals (Zhong, Fu, Xia, Yang, & Shang, 2015). Furthermore, because the knowledge graph emphasizes the relationships between entities or concepts, the process of linking can promote deeper learning engagement compared to the simple relationships in the concept map, and they can help teachers and students obtain more insight into cognition structure and data mining (Liu, Wang, Zheng, Zhang, & Jiang, 2012). Focusing on knowledge graph refinement, expansion and connection is more important than focusing on its construction (Le-Phuoc, Quoc, Quoc, Nhat, & Hauswirth, 2016).

Although in general, both the concept map and knowledge graph enable visualization of knowledge construction, organization of fragmented knowledge and review of prior knowledge, there are some important differences between them. While the concept map reveals the concepts and their relationships, the knowledge graph links concepts and their creators, resources that are associated with concepts and creators, and learners interested in both concepts and creators. As individual knowledge graphs can automatically converge into one whole, learning hotspots and the evolution of knowledge can be identified clearly.

Visualization tools in flipped classroom

In a flipped classroom, self-paced learning outside class and group collaborative learning in class have facilitated the shift from teacher-centered to student-centered learning. However, fragmented learning content and flexible methods of learning have resulted in students suffering from conceptual and navigational disorientation (Wang, Peng, Cheng, Zhou, & Liu, 2011). Visualization tools aid with this by helping to externalize knowledge and its structure (Jacobson & Archodidou, 2000). Using such tools is important for showing the implicit content that students have learned and generated, the process of thinking, as well as the group's member connection and cognitive patterns (Wang, Ran, Liao, & Yang, 2010). The role of visualization tools in a flipped classroom may be to provide real-time evaluation, learning process recording and presentation of effects (Ruan & Zheng, 2017). In order to better understand learners' social, behavioral and cognitive aspects, tools for the monitoring learning can help teachers identify tendencies with their classes and discover individual needs, thus mitigating the difficulties of flipped learning and improving effectiveness (Mazza & Dimitrova, 2007; Zhang & He, 2013).

In this study, the knowledge graph tool in the Learning Cell System (LCS) was used and its effects were compared with the concept map tool implemented in XMind as a part of a learning scenario. During the learning process, students were instructed to create either a knowledge graph or a concept map to collect information and demonstrate knowledge construction. This was conducted in the fifth grade class of an elementary school and learning content for both types of intervention was ancient Chinese poetry from the Tang and Song dynasties. Before class, in class and after class learning activities were conducted to evaluate the learning performance and in-depth thinking effects of each learning tool. Two research questions are addressed as follows:

1. What are the differences in students' knowledge test scores between learning with knowledge graph and concept map in a flipped classroom?
2. What are the differences in students' graph structures (number of concepts at multiple levels, branchings and examples and branching depth) between learning with knowledge graph and concept map in a flipped classroom?

Methodology

Knowledge graph in Learning Cell System (LCS) for a flipped classroom

The knowledge graph in the LCS was used in this study as a part of learning scenarios to support students in constructing and expanding their knowledge structure, focusing on the entity or concept and the semantic relationships, and linking entity information from other student's creations from the converged knowledge graph. Connectivism and collaborative knowledge construction theories were referred and served as the theoretical framework; the knowledge graph in the LCS supported students in construction of knowledge, interconnected different students' knowledge, and shared collective wisdom and experience within the groups (Yu, Yang, Cheng, & Wang, 2015). It visualized the whole learning process and guided students to track others' contribution for group awareness (Pifarré, Cobos, & Argelagós, 2014). Learning resources in the LCS were not only connected by semantic relationships (including similar, hyponymy, precursor, inclusive and equivalence relationships), but also by entity information. This enables students' "learning to learn" by checking other students' individual knowledge graphs as well as the converged graph. The comparison between the individual and converged knowledge graph in the LCS could promote collaborative knowledge construction and better collaborative processes as well as enhance learning performance. The intent of this study was to help students gain a better grasp of ancient Chinese poetry on the basis of using knowledge graphs in the LCS for a flipped classroom, thus facilitating the interaction between students and knowledge, and foster deeper learning.

Before class, the teacher designed and uploaded the learning resources, including video, audio and text, to the LCS, as shown in Figure 1.

After working through the learning resources, students created individual knowledge graphs with nodes and their relationship representing knowledge acquired from the learning resources and domains of knowledge in which students are particularly interested. Figure 2 shows an example of one individual knowledge graph created by a student.

Figure 1: Learning resources of the flipped classroom course
[Colour figure can be viewed at wileyonlinelibrary.com]

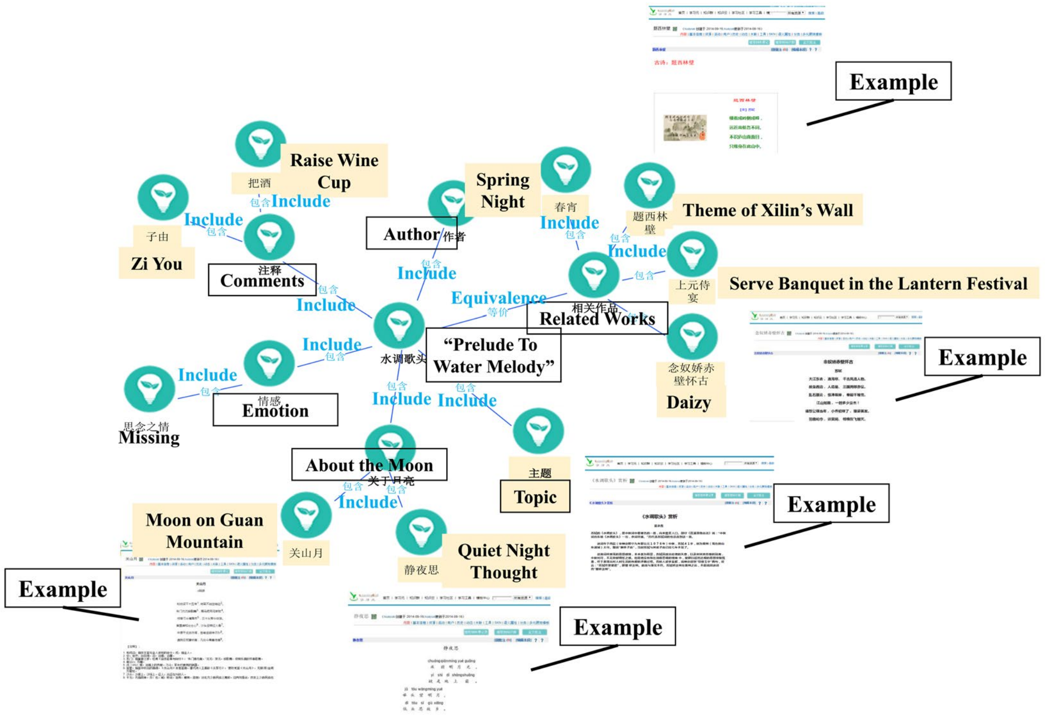

Figure 2: An individual knowledge graph based on the LCS
[Colour figure can be viewed at wileyonlinelibrary.com]

Each student was able to review the knowledge graphs of other learners by viewing the list of knowledge nodes and the list of relationships between knowledge nodes, as shown in Figure 3. As individual knowledge graphs were submitted, the LCS converged them into one comprehensive graph that was aggregated and automatically presented in real time, as shown in Figure 4. The LCS is cohesive, organizing the content generated through the learning process into an orderly whole. It aggregated and classified the same knowledge nodes into the comprehensive one with unique concepts through judgment as well as gathered and converged the individual knowledge graphs according to its existing semantic annotations and hierarchical relationships. When independent or incorrect knowledge nodes existed within the individual knowledge graphs, the teacher would manually determine whether to converge them into the comprehensive one or to delete them.

Concept map in XMind for a flipped classroom

The concept map in this study was implemented in XMind, a popular professional mapping tool that can also be used to draw concept maps. It can be used to simply and quickly construct concept maps of basic knowledge nodes and the relationships between them. Not only it can visually organize concepts and relationships, but also can make creation and deeper analysis possible. In this study, the teacher and students used it frequently and proficiently in their daily teaching and learning. Figure 5 shows an individual concept map generated by a student, and Figure 6 shows the concept maps of the entire class, collated by the teacher.

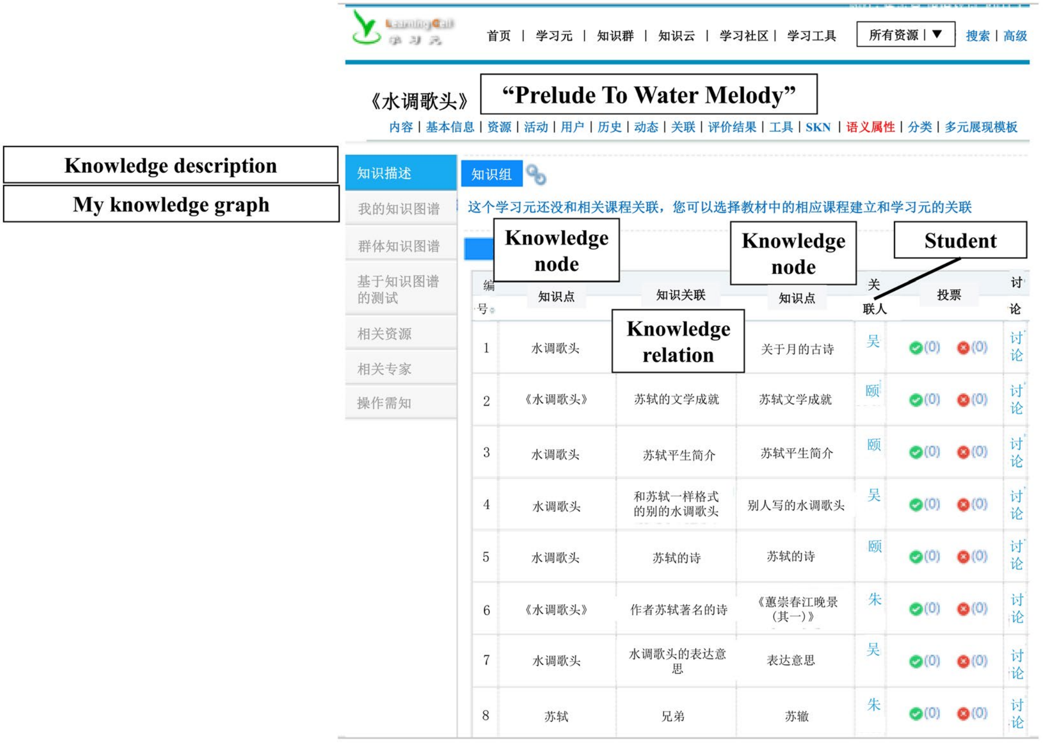

Figure 3: Knowledge nodes and their relations list of the entire class [Colour figure can be viewed at wileyonlinelibrary.com]

Experimental design

To evaluate the learning effects of a knowledge graph compared with concept map in a flipped classroom, an experiment was conducted in an ancient Chinese poetry learning course to compare learning performance between the two visualized learning tools. The objectives of the ancient Chinese poetry learning course were to foster students' understanding of poetry and analysis abilities, as well as to foster deeper learning.

Participants

A total of 74 students (Grade 5, mean age = 11.4 years) and one Chinese teacher participated. All of them were at Tanglang Primary School in Shenzhen, China, which is a public primary school, with a medium level of education quality. Class 1 was the experimental group, with 36 students. Class 2 was the control group, with 38 students. All students were familiar with learning in computer classrooms and the teacher was a full-time primary school teacher with 6 years of Chinese teaching experience in the computer classroom.

Context

The experiment was conducted in computer classrooms in which every student had a laptop. The teacher had a multimedia teaching system with a personal computer and projector, and all computers were able to directly access a wireless network. The LCS was deployed in the experimental class. One week prior to the start of the experiment, participants were trained to use either a knowledge graph or XMind for 1 hour each day for 3 days to ensure that the tools would be

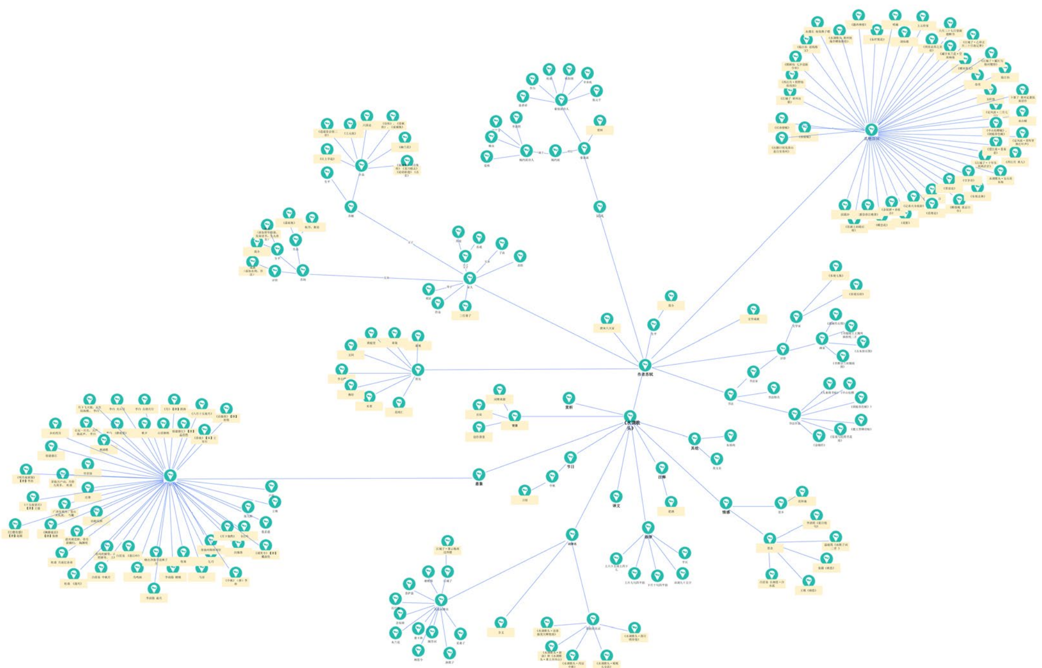

Figure 4: *The converged knowledge graph of the entire class based on the LCS [Colour figure can be viewed at wileyonlinelibrary.com]*

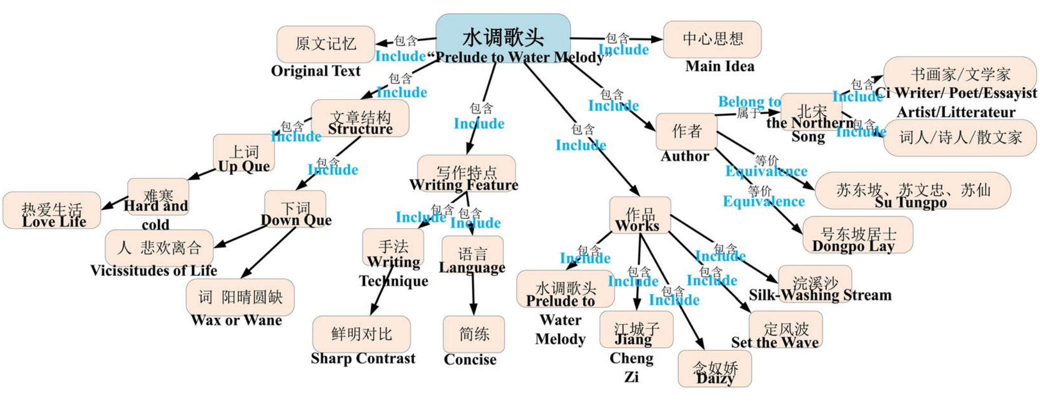

Figure 5: *Individual concept map based on XMind from the control group [Colour figure can be viewed at wileyonlinelibrary.com]*

used frequently and correctly in the flipped classroom. In the experimental group, students were trained to create new nodes and relationships after teacher's demonstration for the first hour. For the second hour, students learned how to view each other's knowledge graphs and the entire class converged the knowledge graph. Over the 3-hour period, students learned how to create examples with the nodes that may include text, picture, audio, video or hyperlinks. In the control group, the teacher and students used XMind frequently and proficiently in their daily teaching and learning. Over the first week, students learned other content with concept map in XMind.

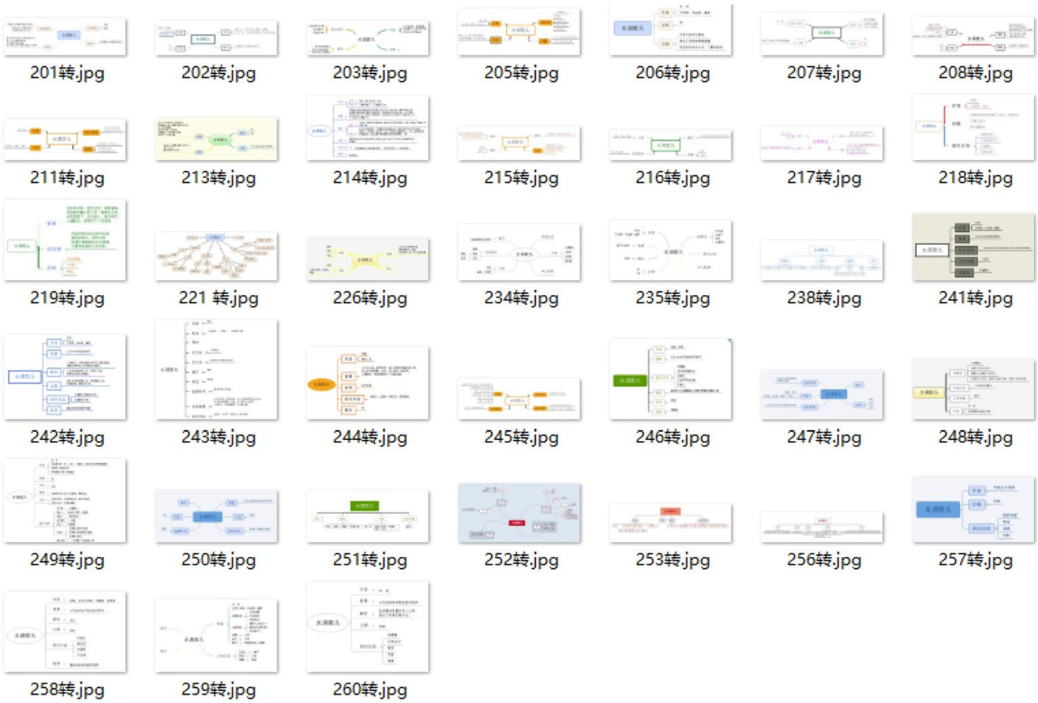

Figure 6: Concept maps of the entire class based on XMind from the control group [Colour figure can be viewed at wileyonlinelibrary.com]

Procedure

The learning procedure is shown in Figure 7. In the first week, students in both the experimental (n = 36) and control groups (n = 38) took the pretest. The experimental group students then learned how to use the knowledge graph in the LCS, while the control group students learned with concept map in XMind. Over the subsequent 4 weeks, students studied four ancient Chinese poems, including "Liangzhou Words" (frontier poetry), "Prelude to Water Melody" and "In the Son" (patriotic poetry), and "Summer" (nostalgic poetry) respectively. During each week, students learned one ancient Chinese poem in three stages: before class, in class and after class. Before class, both groups of students studied materials provided by the teacher. Students in the experimental group created individual knowledge graphs in the LCS and were able to view the converged knowledge graph of the entire class, which brought together new nodes and details from other students and supplemented the individual graphs. In the control group, students created individual concept maps in XMind, viewed the collated concept maps of other students and supplemented the individual ones. The differences between the two groups were in the ways of viewing others creations that aimed to enhance reflection on and improvement of the individual ones, which is one of the prerequisites for fostering deeper learning and more complex knowledge structures (King & Tran, 2017). In class, students continued their learning process and cooperated to resolve any questions. These questions could arise from a lack of attention to the knowledge as well as in-depth analysis of domains of students' interests culled from knowledge graphs and concept maps. As lead-in questions, students cooperated to solve them in groups and then shared their answers in class. After class, students complemented and broadened the individual knowledge graphs in the experimental group and in the control group with concept maps.

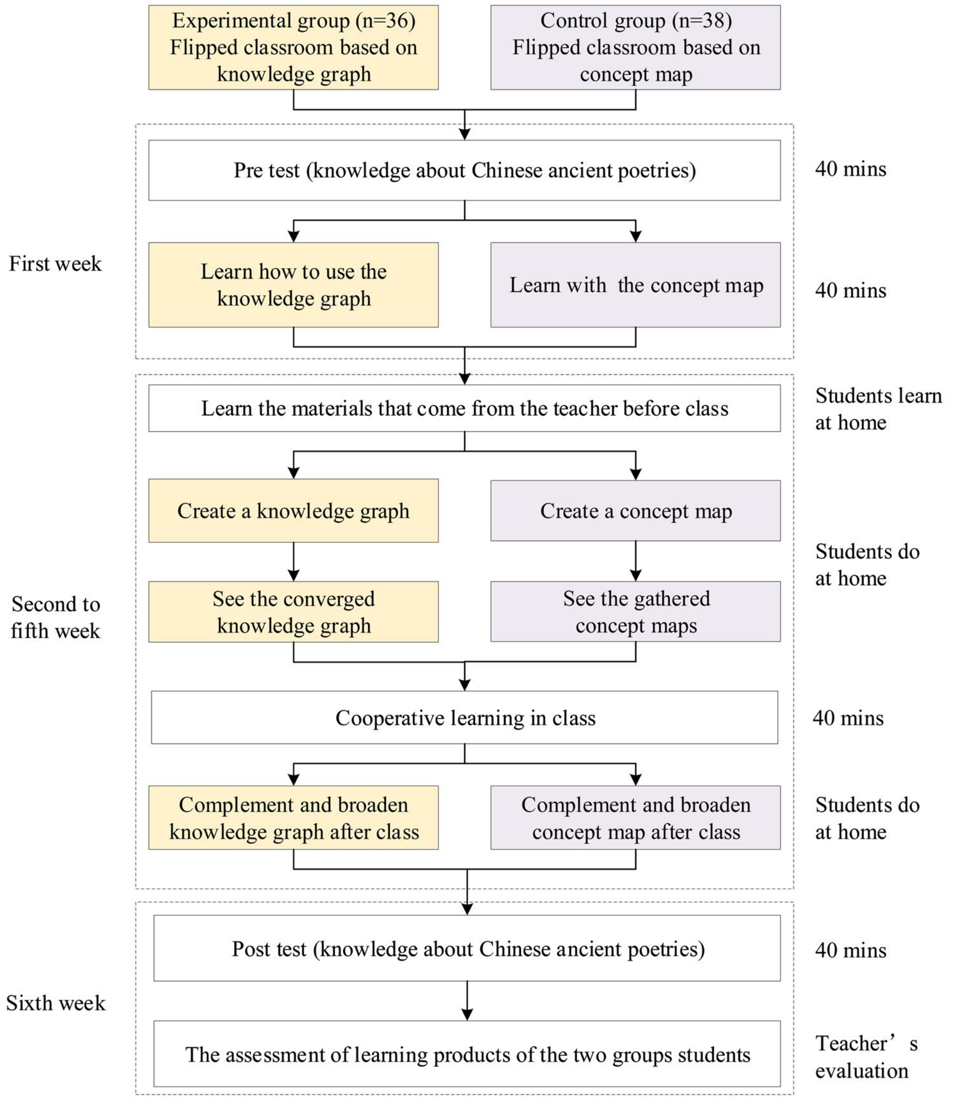

Figure 7: Experimental process
[Colour figure can be viewed at wileyonlinelibrary.com]

After that, students from both groups took the posttest, while the teacher provided assessment of the learning products.

The only difference in activities and process between the two groups was the learning tool: students in the experimental group learned with knowledge graph, while students in the control group learned with concept map. Students took the posttest in the sixth week.

Instruments

The instruments employed in this study included ancient Chinese poetry learning tests and scoring criteria for concept maps. Periodic tests of ancient Chinese poetry were held by the Shenzhen Education Bureau. Test A and B were used in each periodic test, A as the pretest and B as the posttest. Each test was 100 points in total and was composed of 20 single choice questions (2 points per question, a total of 40 points), 12 fill-in-the-blank questions (2 points per blank, a total of 40 points) and 20 supplementary poem questions (1 point per question, a total of 20 points); these contained questions on literary knowledge, poetry content, criticism and appreciation of poems in the Tang and Song dynasties. The scoring criteria for the structured graph developed by Novak and Gowin (1984) were employed, which includes six dimensions with concepts, relationships, branchings, hierarchies and examples. The number of concepts and relationships indicate the extent of knowledge in the domain of ancient Chinese poetry; branchings show the progressive differentiation of knowledge of ancient Chinese poetry; hierarchies represent domain knowledge subsumption; examples represent the mastery of knowledge. Using this evaluation method, the study compared the experimental group (using the knowledge graph) with the control group (using the concept map) and analyzed the number of concepts and the hierarchies they belonged to, the numbers of branchings and their depth and the number of examples related to ancient Chinese poetry.

Data analysis

Analysis of learning performance

The aim of the study was to examine learning performances with knowledge graph and concept map in a flipped classroom. The mean values and standard deviations of the pretest scores were 79.97 and 10.53 respectively, for the experimental group, and 75.44 and 16.62 respectively, for the control group. The t test result ($t = 0.49$, $p > 0.05$) shows that there was no significant difference between the two groups, as shown in Table 1. The two groups of students had equivalent prior knowledge in ancient Chinese poetry before this course of learning.

In order to avoid any influences between the pretest and posttest, after learning four ancient Chinese poems during the second to fifth week, the one-way analysis of covariance (ANCOVA) was employed to evaluate performances in the experimental group and in the control group by the pretest scores as the covariate and the posttest scores as dependent variables. Levene's test of determining homogeneity of variance was not violated ($F = 0.50$, $p > 0.05$), indicating that the assumption is tenable and the ANCOVA results can be used to interpret the relationships between the students' tested prior knowledge and their learning achievement in the posttest. Table 2 shows the results of the posttest scores in both groups. The adjusted means and standard deviation of the posttest scores were 93.46 and 0.82 respectively for the experimental group, and 88.04 and 0.77 respectively for the control group. The experimental group's posttest scores were significantly higher than those of the control group; the results ($F(1,80) = 23.28$, $p < 0.001$) display a significant difference between the two groups. This implies that the students who learned Chinese ancient poetry based on the knowledge graph showed significantly better learning outcomes than those who learned based on the concept map.

Analysis of learning products

Learning products from the LCS and XMind were examined in order to better understand the students' actual learning performance and the effects of knowledge graph and concept map in a flipped classroom. The students displayed the most interest in "Prelude to Water Melody" as it

Table 1: Results of t test for pretest scores

Group	*N*	*Mean*	*SD*	*t*
Experimental group	36	79.97	10.53	0.49
Control group	38	75.44	16.62	

Table 2: Results of one-way ANCOVA for posttest scores

Group	*N*	*Mean*	*SD*	*Adjusted mean*	*Adjusted SD*	*F*
Experimental group	36	93.92	4.65	93.46	0.82	23.28***
Control group	38	87.63	10.09	88.04	0.77	

***$p < 0.001$.

had been featured in a popular song by a famous singer; this led students to spend more time and submit more work on this poem, compared with the others.

Table 3 shows the number of concepts and their hierarchies. As shown in the knowledge graphs and concept maps, the first-level nodes were about the author, background, the Ci-pai poems (a style of poetry) and appreciation for "Prelude to Water Melody," which was the central node. The second-level nodes were subthemes of the first-level nodes, while the third-level nodes were subthemes or examples for the second-level nodes and so on. Statistical analysis showed that students in the experimental group created 215 first-level nodes in total (mean: 5.97), compared with 179 (mean: 4.71) for the control group. The results for second-level nodes showed that the students created 547 in total (mean: 15.19) in the experimental group and 310 (mean: 8.16) in the control group respectively. Students in the experimental group created 185 third-level nodes in total (mean: 5.14) and there were 57 (mean: 1.50) created in the control group respectively. The mean comparison of concept and hierarchy in the learning products between the two groups is shown in Figure 8.

For a more direct representation of the difference in performance, the following formula expresses the percentage of mean difference by which the experimental group performance exceeded that of the control group is as follows:

$$\text{Percent of Mean Difference} = \frac{\text{Mean}_{\text{Experimental Group}} - \text{Mean}_{\text{Control Group}}}{\text{Mean}_{\text{Control Group}}} \times 100\%.$$

The percentages of the mean difference were 26.75%, 86.15%, 242.67% and 10100%, for the first-, second-, third-, and fourth-level node conditions respectively. The results revealed that the numbers and means for every node level were significantly higher in the experimental group compared with the control group.

Table 4 shows the statistical results for the number of branchings. Based on the syllabus, course objectives and the teacher's experience, students were required to learn poetry by focusing on various aspects, including the author, background, introduction of the Ci-pai style of poem, translation, appreciation and imagery. Counting the numbers of these seven aspects included in the knowledge graphs and concept maps was important for measuring whether the students met the requirements of the lesson and to ensure learning quality. As shown in knowledge graphs and concept maps, students in the experimental group created 31 branchings in total regarding the author (mean: 0.86) compared with 36 branchings (mean: 0.95) in the control group. The mean comparison of branching in learning products between the two groups is shown in Figure 9.

Students in the experimental group created a total of 11 branchings for background (mean: 0.31) while those in the control group created 19 (mean: 0.50). "Prelude to Water Melody" was not only the title of the poem, but also a Ci-pai poem; understanding this point is a prerequisite for

Table 3: Statistical results for the numbers of concepts at multiple levels

Concepts and hierarchies	*Group*	*N*	*Number*	*Mean*	*Percent of mean difference*
First-level nodes	Experimental group	36	215	5.97	26.75%
	Control group	38	179	4.71	
Second-level nodes	Experimental group	36	547	15.19	86.15%
	Control group	38	310	8.16	
Third-level nodes	Experimental group	36	185	5.14	242.67%
	Control group	38	57	1.50	
Fourth-level nodes	Experimental group	36	110	3.06	10100%
	Control group	38	1	0.03	
Total	Experimental group	36	1057	29.36	104.10%
	Control group	38	547	14.39	

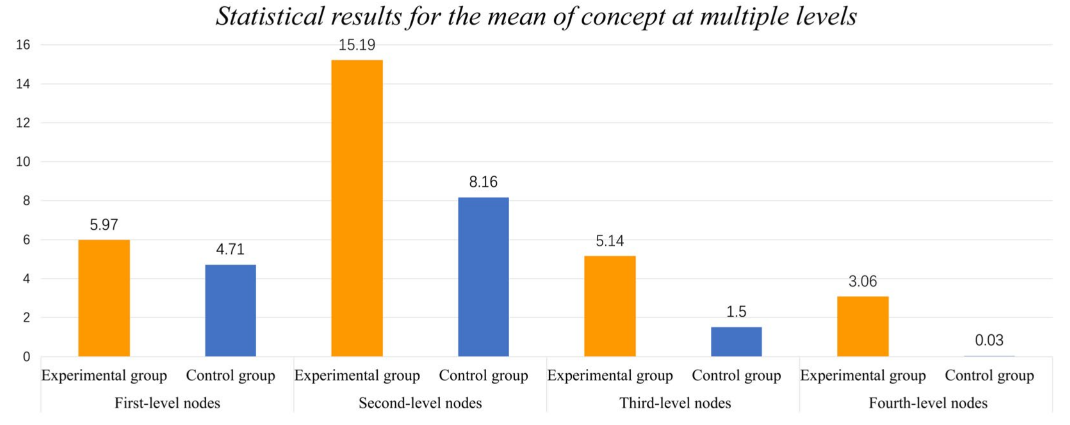

Figure 8: Mean comparison of the number of concepts at multiple levels [Colour figure can be viewed at wileyonlinelibrary.com]

learning ancient Chinese poetry from the Tang and Song dynasties. Students in the experimental group created 11 branchings for the introduction of the Ci-pai poem (mean: 0.31), while those in the control group created 14 (mean: 0.37). The branching for translation was translating classical Chinese into modern Chinese, which was also a prerequisite for understanding the meaning of the poem. It was found that students in the experimental group created seven branchings for translation, compared with 14 (mean: 0.37) in the control group.

Furthermore, appreciation includes the infiltration and experience of poetry, requiring students to pay attention to the effects of the subtleties of language and their implications for understanding the poem. Students created 21 branchings of appreciation (mean: 0.58) in the experimental group compared with 20 branchings (mean: 0.53) in the control group. The imagery of the poetry refers to the expression of emotion using metaphor. For example, the moon could represent "longing," "a bleak place" or "newness," while a willow could represent "remaining," and a boat could represent "relaxation" and "freedom." The results revealed that students created 30 branchings of imagery (mean: 0.83) in the experimental group compared with six branchings (mean: 0.15) in the control group.

Table 4: Statistical results for the numbers of branchings

Branching	*Group*	*N*	*Number*	*Mean*
Author	Experimental group	36	31	0.86
	Control group	38	36	0.95
Background	Experimental group	36	11	0.31
	Control group	38	19	0.50
Introduction of the Ci-pai poem	Experimental group	36	11	0.31
	Control group	38	14	0.37
Translation	Experimental group	36	7	0.19
	Control group	38	14	0.37
Appreciation	Experimental group	36	21	0.58
	Control group	38	20	0.53
Imagery	Experimental group	36	30	0.83
	Control group	38	6	0.16

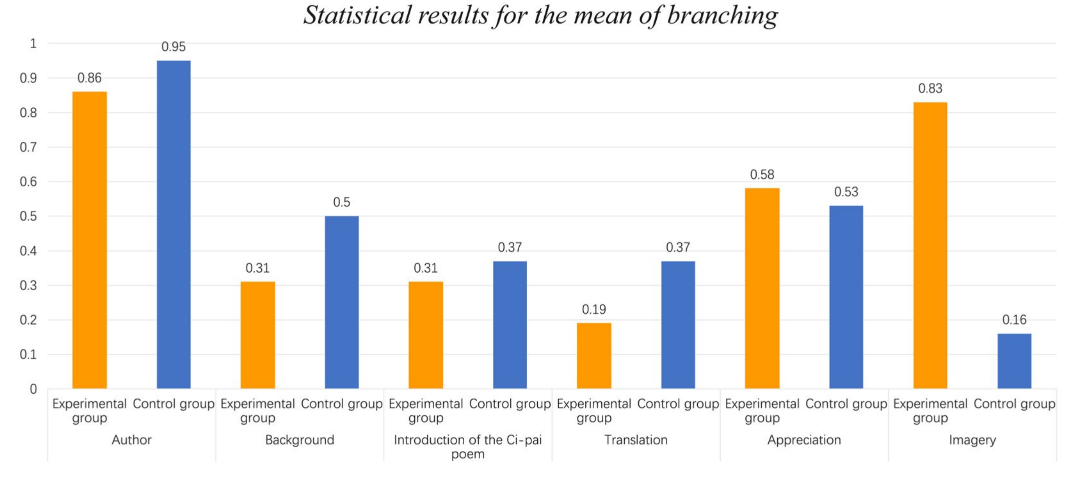

Figure 9: Mean comparison of branching
[Colour figure can be viewed at wileyonlinelibrary.com]

Table 5 shows the statistical results for the branching depth values. This measure was used to understand students' knowledge systems, particularly their personalized knowledge structure beyond the requirements of the course standards. According to the scoring criteria for concept map levels, the depth of the level can be used as the weight of the level. Thus, the weight of the first-level was 1, the weight of the second-level was 2 and so on. Meanwhile, the number of the first-level was x_1, the number of the second-level was x_2 and so on. Consequently, the formula for calculating the average depth of the concept map was $\overline{BD} = \frac{1 \cdot x_1 + 2 \cdot x_2 + \cdots + n \cdot x_n}{x_1 + x_2 + \cdots + x_n}$. The results revealed that the average depth was 2.18 in the experimental group and 1.78 in the control group.

Table 6 shows the statistical results for the examples reflecting how well students mastered knowledge of ancient poetry. These data were created to supplement and expand the knowledge nodes which were explicit representations of tacit knowledge. As shown in the knowledge graphs and concept maps, it was found that students in the experimental group created 214 examples (mean: 5.94) compared with 41 (mean: 1.08) in the control group, and the mean percentage difference

Table 5: Statistical results for branching depth

Branchings depth	Group	N	Number	Depth value
BD_1	Experimental group	36	215	215
	Control group	38	179	179
BD_2	Experimental group	36	547	1094
	Control group	38	310	620
BD_3	Experimental group	36	185	555
	Control group	38	57	171
BD_4	Experimental group	36	110	440
	Control group	38	1	4

Table 6: Statistical result for the numbers of examples

Group	N	Number	Mean	Mean percentage difference
Experimental group	36	214	5.94	450%
Control group	38	41	1.08	

was 450%. The mean comparison of examples in learning products between the two groups is shown in Figure 10.

Analysis of students' work

For an in-depth understanding of students' work, Figures 2 and 6 show examples of the work of individual students from each group. Figure 2 shows the content of an individual knowledge graph, with first-level nodes of "Author," "Comments," "Related Works," "Topic" and "About the Moon and Emotion." Figure 6 shows the content of an individual concept map, with first-level nodes of "Author," "Genre," "Time," "Appreciation," "Rhesis" and "Basic information." Within these nodes, "Author," "Comments," "Related Works," "Structure," "Original Text," "Genre," "Time" and "Basic information" belonged to the lower order thinking skills in Bloom's taxonomy of educational objectives, involving remembering and understanding. These nodes were included in the teaching instructions and could be directly found in reference books or in the internet. The nodes "Topic," "About the Moon," "Emotion," "Main Idea" and "Rhesis" involved the imagery and appreciation of the poem. The content of these nodes was based on in-depth and personalized understanding. Comparison of the two students' work indicates that the content of the nodes in the knowledge graph required more in-depth thinking and refinement compared with that in the concept map.

Moreover, as shown in Figure 11, the example knowledge graph was created by individual students using both images and text. These examples became learning resources for other students, and even for the teacher. Thus, questions designed by the teacher based on knowledge graphs were typically about "why" and "how," and in contrast, the teacher's questions based on concept maps were more likely to be in the form of "what is…?" and "right or wrong." These results indicate that the content based on the knowledge graph was broader and deeper than the content based on the concept map.

Discussion

The study aimed to explore students' in-depth thinking and effective learning in a flipped classroom and to compare the effects on learning performance and products between knowledge graph and concept map. The results of the data analysis are discussed as follows.

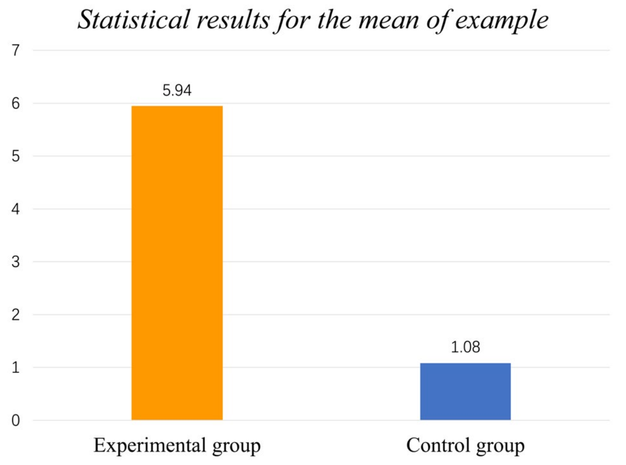

Figure 10: Mean comparison of example
[Colour figure can be viewed at wileyonlinelibrary.com]

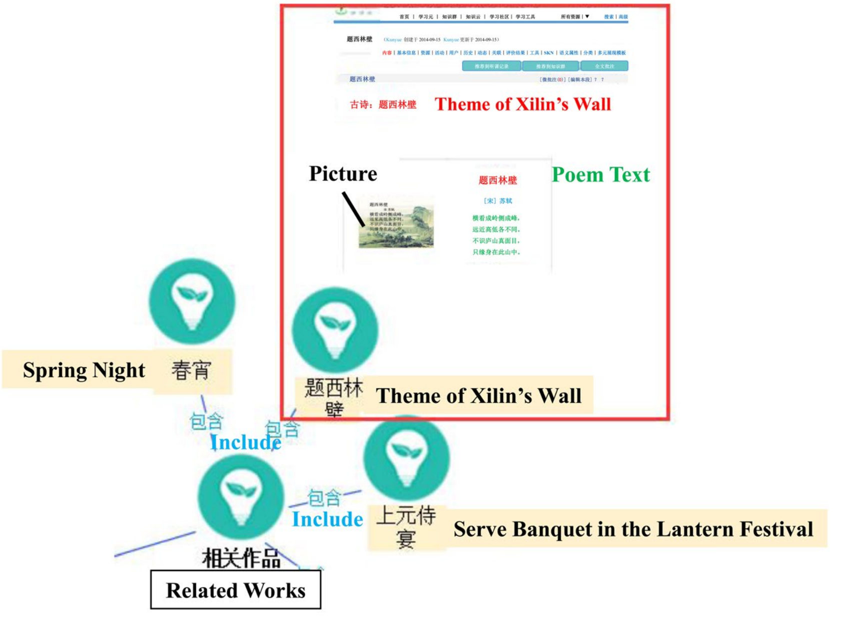

Figure 11: Example of knowledge graph
[Colour figure can be viewed at wileyonlinelibrary.com]

The experimental results show that learning with knowledge graph and concept map not only can improve learning performances, but also can foster active learning. In the current study, students in the two groups constructed and expanded their knowledge graphs and concept maps before class, resulting in well-prepared learning at home and sufficient basic knowledge, which were the foundation for developing higher order thinking abilities. The findings appear to conform to the findings of Clark (2013) who reported that students needed to build on their previous knowledge for subsequent learning. In addition, concept maps were collated from the teacher, and the teacher and other students were able to see each individual submission. A knowledge graph for the entire class was automatically converged by the LCS. Students could see other students' knowledge graphs as well as the comprehensive graph. Comparing with others' concept maps or knowledge graphs, prompted students' reflection and in-depth understanding of the knowledge.

The analysis of the students' performance indicated that students who learned with knowledge graph displayed better performances than those who learned with concept map. The analysis of students' products and individual work showed that more concepts, hierarchies and examples on expanded knowledge were created with knowledge graph than with concept map. The deeper the hierarchy, the more concept nodes the experimental group created than the control group. Meanwhile, the branchings and branching depth reflected the achievement of course objectives. The analysis of entities or concepts and their relationships promoted deeper learning engagement, thus producing deeper learning outcomes. According to Bloom's taxonomy of educational objectives, the experimental group students paid more attention to "Appreciation" and "Imagery," which pertain to a generation of deeper learning, while those in the control group paid more attention to the surface learning of the poem. This indicated that visualizations of group content was beneficial to group awareness. The knowledge graph supported linking to entity information created by others, which thus promotes individual reflection in students. These accord with the effects of knowledge graph as described by Lu *et al.* (2016), who indicated the effectiveness of using the knowledge graph to help students reflect on their own work and to facilitate learning how to actively solve problems. It also showed the support for and promotion of generative learning though the knowledge graph. These findings are in accord with the effects of learning with knowledge graph reported by several researchers, including Lee and Segev (2012), Hao, Yan, Gong, Wang, and Lin (2014) and Balaid, Rozan, Hikmi, and Memon (2016), who indicated the effectiveness of knowledge graph for increasing organizational effectiveness, navigating knowledge users and improving the quality of extracted information. This result also reflects Bandura's (1997) the social learning theory, which proposes that learning is considered to occur via the observation of other learners' behavior or learning products. Moreover, in the current study, students constructed and expanded their own knowledge graphs, reflecting the process of deepening cognition (Anderson, 2001).

For the teacher, compared with the gathered concept maps, viewing the converged knowledge graph enabled identification of knowledge gained by students, domains of interest and aspects that had not been given adequate attention. Visualizing and accurately analyzing the overall learning situation before class provided the precondition to determine the key points and instructional difficulties, thus avoiding repetition of superficial knowledge and ineffective teaching procedures. However, the collated concept maps did not enable the teacher to grasp students' overall learning situation before class, making it more difficult to design deeper questions for collaborative learning in class. For example, in the control group, typical lead-in questions were "What are your problems?," "Which sentence is an obstacle?" and "Who can read and paraphrase the verse?." However, the question design in the experimental group changed from paraphrasing poetry to understanding its emotional expressions or metaphors. For example, in the current study, the lead-in question for teaching "Prelude to Water Melody" was "Please talk about one word or one sentence that makes you feel the strongest emotion, and describe how you feel" and "Talk about your impressions on the moon in this poem." This reflected a productive classroom, focused on heterogeneous changes and higher order thinking abilities (Pehmer, Gröschner, & Seidel, 2015).

In summary, the findings revealed significant differences in learning performances, as well as breadth and depth of knowledge between the two learning products. Students who learned ancient Chinese poetry with knowledge graph performed better than those who learned with concept map according to the criteria. In terms of effects of knowledge graph and concept map for facilitation, the knowledge graph appeared to have greater positive effects than the concept map on deeper learning and in-depth thinking.

Although our measures of learning performances and products indicated that learning effects of the knowledge graph were greater than those of the concept map, some limitations of the flipped classroom should be considered for this research as well. First, we examined a relatively small sample of only 74 students and one teacher. Future research should include more participants. Second, the experimental content involved a single subject, ancient Chinese poetry. Future studies should examine this issue within multidisciplinary subjects and topics.

Conclusion and implication

The main outcome of this study was to demonstrate the effectiveness of knowledge graph for learning ancient Chinese poetry from the Tang and Song dynasties in LCS scenarios and tasks. Comparison between the learning effects of knowledge graph and concept map revealed that the knowledge graph had greater positive impacts for effective, generative and deeper learning. Moreover, the use of knowledge graph increased the depth of teaching design and practice. The reasons behind the different results between the two learning products would be as follows. First, the converged knowledge graph visualized the consensus content using a group awareness tool and may have been conducive to the realization of self-paced learning before class. Compared to the individual concept maps which existed separately, this may have reduced the cognitive load from repeatedly viewing other graphs. In fact, in this study, fewer students in the control group than the experimental group were able to view all the other concept maps and compare them with their own. Second, viewing entity information created by others may have encouraged the students engaging in active learning of the poems. It was conducive to deeper cognitive engagement and discussion of deeper questions in class. Third, the teacher could rapidly and directly understand the learning progress of the entire class by viewing the converged knowledge graph. Compared with viewing each individual student's concept map, this may have reduced the time and load of teaching preparation. Meanwhile, it helped resolve the conflict between teaching presupposition and actual learning impacts.

The individual knowledge graphs highlighted the focus on the process of learners' knowledge construction as well as the reflection of learning content and relevance. The converged knowledge graph reflected a focus on implicit content such as the form and degree of collective wisdom and experience in support for individual learning. Learning with knowledge graph in a flipped classroom could enhance students' initiative in autonomous learning, promote students' in-depth thinking and internalization of knowledge, and support the achievement of deeper learning goals.

The current findings have several implications for Chinese teachers in flipped classrooms. First, the knowledge graph is a potentially useful learning tool, but when teachers and students lack adequate relevant knowledge and experience on how to employ it, the learning process may be time-consuming. Second, compared with learning with concept map, learning with knowledge graph can better foster deeper learning and in-depth thinking in a flipped classroom. However, teachers should view the converged knowledge graph with caution and adjust their in-class questioning strategies accordingly in order to achieve better learning outcomes.

It may be valuable for future studies to examine this approach with other subjects and topics. Meanwhile, in order to foster deeper learning and in-depth thinking in a flipped classroom using knowledge graph, improved instructional cases and learning products should be developed.

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Statements on open data, ethics and conflicts of interest

Due to privacy issues, data from this study can be accessed for the purpose of verifying results and findings by contacting the authors.

This study was conducted and approved under the ethical guidelines at the school. The participants were duly informed of the research objectives, and content and all gave informed consent.

There are no potential conflicts of interest in the work.

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