Interactive Learning Environments

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/nile20

Knowledge map-based online micro-learning: impacts on learning engagement, knowledge structure, and learning performance of in-service teachers

Ning Ma, Feilong Zhao, Peng-Qin Zhou, Jun-Jie He & Lei Du

To cite this article: Ning Ma, Feilong Zhao, Peng-Qin Zhou, Jun-Jie He & Lei Du (2021): Knowledge map-based online micro-learning: impacts on learning engagement, knowledge structure, and learning performance of in-service teachers, Interactive Learning Environments, DOI: 10.1080/10494820.2021.1903932

To link to this article: https://doi.org/10.1080/10494820.2021.1903932

Published online: 25 Mar 2021.

https://doi.org/10.1080/10494820.2021.1903932

Knowledge map-based online micro-learning: impacts on learning engagement, knowledge structure, and learning performance of in-service teachers

Ning Ma [a,b], Feilong Zhao[a], Peng-Qin Zhou[a], Jun-Jie He[a] and Lei Du[a]

[a]School of Educational Technology, Faculty of Education, Beijing Normal University, Beijing, People's Republic of China; [b]Advanced Innovation Center for Future Education, Beijing Normal University, Beijing, People's Republic of China

ABSTRACT

Online teacher professional development is widely regarded as a promising way to improve the quality of teachers and the effect of teaching. Micro-learning, which has the potential to fit the learner's personalized learning needs through a variety of small educational resources and flexible learning opportunities, could be an efficient way for the online teacher professional development. However, the scattered knowledge points and fragmented learning time in micro-learning may limit the learner's comprehension and the construction of knowledge. In this study, a knowledge map-based online micro-learning system was developed to solve this problem. To verify the effectiveness of the proposed system, a quasi-experiment was conducted during a three-week online course for teachers' professional development. A total of 42 in-service Mandarin teachers participated in the course, and were divided into two equal groups. An experimental group learned by using a knowledge map tool while a control group learned the same contents in the form of the conventional list type. The results indicate that the experimental group outperformed the control group in terms of learning engagement, and showed a clearer and more complete knowledge structure. Furthermore, micro-learning coupled with knowledge maps was found to improve the teachers' learning performance.

ARTICLE HISTORY
Received 10 November 2020
Accepted 11 March 2021

KEYWORDS
Knowledge map; micro-learning; teacher professional development; knowledge structure; learning engagement

Introduction

In an era marked by technological changes and increasing global connectivity, teacher professional development (TPD) has attracted the interest of educational foundations and governments in many countries (Kennedy, 2016). Numerous studies have reported that well-designed professional development programs can help teachers improve the quality of their instruction and hence better educate their students (Gore et al., 2017; Koh, 2019). Previous studies have also shown that if teachers receive effective professional development training, they are more likely to be innovative in terms of their teaching skills and perspectives (Chen et al., 2016). Hence, TPD is widely regarded as the most promising way to improve the quality of teachers and the effect of teaching (Gore et al., 2017).

Given the need to support TPD, educational foundations around the world are spending large sums on the design and implementation of TPD programs (Lindvall & Ryve, 2019). In recent years,

CONTACT Ning Ma horsening@bnu.edu.cn

due to such limitations of conventional offline workshops for TPD as a lack of participation and the creation of usable pedagogical knowledge (Cho & Rathbun, 2013), online teacher professional development (oTPD) has been encouraged by many scholars (Parsons et al., 2019). oTPD offers teachers a flexible and cost-effective option for professional development in a myriad of educational topics (Chen et al., 2009; Powell & Bodur, 2019). Furthermore, online communities and networks can provide teachers with the possibility of sharing opinions.

Among the most notable trends of online learning is the design and implementation of small chunks of learning resources to fit individual learning needs, called micro-learning (Nikou & Economides, 2018). Jomah et al. (2014) claimed that since micro-learning can help learners acquire a large number of valuable learning materials flexibly in time according to their personalized learning needs, and can be viewed as an efficient way to improve learning. However, some researchers have argued that features of the micro-learning approach can adversely influence students' learning outcomes, such as fragmented learning time, scattered learning contents, and a potentially unlimited number of sites available for learning (Fu et al., 2019; Huo & Shen, 2015). For example. Hung et al. (2014) claimed that in the micro-learning approach, learners generally learn with a number of short instructional videos, each of which presents a concept or a piece of knowledge. This can influence their understanding of the entire knowledge structure. Therefore, it is important to provide a strategy or tools to help learners organize what they have learned.

Shaw (2010) has verified that knowledge maps have an advantage when it comes to simplifying relational complexity. Thus, using knowledge maps to present e-learning materials can make the structure of learning contents clearer and cause learners to easily digest them in a short time (Hwang et al., 2018). We have in past investigated the application of a knowledge map in to an online micro-learning course. Our hypothesis had then been that micro-learning coupled with a knowledge map is more effective than learning without a map. During our research, we noticed a trend whereby previous studies had focused heavily on the effects of knowledge maps in traditional learning rather than e-learning (Shaw, 2010). Although there is considerable literature on professional development, including teachers' preservice preparation and evaluations of methods to improving teaching, little systematic research has centered on knowledge map-based learning as a possible approach to TPD (Hwang et al., 2019).

In this study, a knowledge map-based micro-learning system is developed and a quasi-experiment is conducted to verify its positive influence on in-service teachers' learning engagement, knowledge structure, and learning performance.

Literature review

Micro-learning

Micro-learning refers to a learning approach based on small learning units and short, focused learning activities (Nikou & Economides, 2018). In micro-learning, learners can obtain various micro-contents, including definitions, brief video segments, and quizzes, and a micro-assessment so that their knowledge can be evaluated without requiring special testing arrangements (Nikou & Economides, 2018). Thus, micro-learning can be easily integrated into a learners' daily life to enable a flexible learning model that reflects the learners' personal needs.

In addition to the above, micro-learning is reported to have a positive influence on learning and a learner's overall satisfaction (Stohr et al., 2019). Previous research has shown that micro-learning conforms to the general model for learners to process information in small, manageable knowledge chunks, and therefore can enable them to better study and retain information without an information overload. For example, Slemmons et al. (2018) claimed that the attention spans of learners are often limited to 15 min. Small, adaptive chunks of resources give learners the opportunity to make the best use of every fragmented piece of time to engage in learning (Zhang, 2016). The micro-learning approach provides abundant online resources to promote instant learning according to individual needs (Souza & Amaral, 2014). These small and fragmented learning resources' not only contribute to quick assimilation, but also make it possible to learn without the limitations of a fixed time and location (Yang et al., 2017), which is a significant convenience for on-the-job personnel.

Although the advantages of micro-learning have been widely recognized, some have raised doubts about it, such as the disadvantage of deep thinking construction whereby it can easy to lead to learning disorientation. Zhang et al. (2016) claimed that fragmented micro-learning contents require that learners be highly concentrate and reflective, and an online learning environment is fraught with unpredictable distractions that may lead to a highly scattered learning experience (Brita-Paja et al., 2019). Moreover, in a mass of micro-learning resources, learners usually lack sufficient knowledge to construct an appropriate logical structure consisting of the relevant knowledge points, which may hinder their construction of deep thinking (Huo & Shen, 2015). In short, current research on micro-learning has provided mixed results, but it appears that micro-videos in conjunction with other learning approaches may have the potential to improve learning (Stohr et al., 2019).

Knowledge maps

Knowledge maps, as a knowledge visualization tool, are used to show the relationships between learning sources and knowledge (Lee & Segev, 2012). They are node-link representations in which ideas are located in the nodes, and are connected to other, related ideas through a series of labeled links (O'Donnell et al., 2002). Knowledge maps can be viewed as an important cognitive strategy and resource for human creativity, discovery, and problem-solving (Lv et al., 2016; Shaw, 2019), and has been used to solve a wide range of problems in education and instructional design (Ma et al., 2020). For example, Hou et al. (2016) proposed using a Web map-based mind tool to improve learners' spatial thinking and cooperative ability, which may have a positive impact on their learning attitudes. With the development of visual computer-based systems, the importance and complexity of visualization will surely increase (Cheng & Chu, 2018).

In addition to the above, there are many advantages of using knowledge maps in the learning process. Some scholars have claimed that knowledge map-based e-learning materials can improve learning performance and learning attitude (Al-Dmour et al., 2017; Chang et al., 2018; Cheng & Chu, 2018). Knowledge displayed in a map can assist learners understand the various correlations and knowledge structures (Mutodi & Chigonga, 2016). The knowledge map can be regarded as a navigation tool to show the flow of knowledge and guide the learner's process of learning (Ma et al., 2020). This has the potential to help learners concentrate on the learning process and transform tacit knowledge into explicit knowledge (O'Donnell et al., 2002). Furthermore, previous studies have indicated that knowledge maps are useful for knowledge construction by helping learners recognize important knowledge points and the relationships between them, and to organize the knowledge systematically (Lee & Segev, 2012). By referring to these previous studies, this research combines knowledge maps with micro-learning to improve teachers' learning engagement, knowledge structure, and learning performance.

Knowledge map-based online micro-learning system for in-service teachers

The design of the Knowledge Map-based Online Micro-Learning (KM-OML) system in our research is motivated by the following considerations:

First, the knowledge map tool should present relationships between the core knowledge points or chunks. In this research, based on the definition of the relationships among the knowledge points (Shaw, 2010), we adopted three core relationships: pre-order or successor, correlativity, and sharing. For example, suppose we have two knowledge points A and B, and the first relationship is that if A must be learned before B, or learning B is directly supported by A, we should call A the pre-order point of B, and should call B the successor of A. Second, correlativity means that the two knowledge points are independent of each other, and there is no mandatory requirement of a learning sequence, but A can enrich the learning of B and vice versa. Third, if A and B have some the same sub-contents, we call the relationship between them a sharing relationship. The knowledge map tool should reveal the relationships between knowledge points, embody tacit knowledge, and reduce the limitations from a single, linear relationship. In addition, during the learning process, the map tool should help learners avoid learning disorientation by helping them form a graphic memory to recognize the position of knowledge points in the knowledge system and establish a subjective one in their mind.

Second, the knowledge map should support self-selection and personalized learning as a navigational tool. This will enable learners to choose the learning contents according to their personal interests and learning situations. In short, learners can learn at their own pace.

Third, the knowledge map should be a tracking and reflection tool. At the beginning, all knowledge points are red, which means that they have not been learned. If the learner selects a knowledge point, the point turns yellow. When the learners have finished learning the knowledge point and completed all corresponding online exercises, the point turns green. The next point turns green only when all of its pre-order knowledge points have been completed.

In this study, a teacher training course is designed for online micro-learning, called Integrating Literacy, Reading, and Writing in Mandarin Learning. It is divided into 20 knowledge points (as shown in Table 1) and contains three modules. Each is divided into several, more detailed, learning contents called knowledge points. Likewise, the projected learning time of each knowledge point is given in the last column of the table below.

Figure 1 shows the knowledge map interface of the KM-OML system. The map is composed of three parts. The title of the course is represented by the rectangle, knowledge modules, and knowledge points. Every module has several knowledge points and sub knowledge points, which are represented in three colors (red, green, yellow) according to their learning status. For example, green means "has finished," red means "has not started," and "yellow" means "has started, but not finished." The different types of arrows between the knowledge modules and knowledge points represent the different relationships in the map.

Clicking any knowledge point opens a webpage that contains the corresponding learning contents and materials divided into three parts: leading into the learning situation, micro-videos for learning, and exercises for evaluation and knowledge transfer (see Figure 2). During the learning process, the system can automatically track and record the participants' learning processes, such as learning time and online interaction. Furthermore, it can evaluate their learning based on the

Table 1. The outlines of knowledge points of micro-learning.

Modules	Knowledge points	Learning time (minutes)
Core theories	Problems and current situation in Mandarin teaching	10
	Children's new thinking development theory	8
	Integration theory of ICT into Mandarin teaching	10
	Theory of creative thinking development in Mandarin teaching	5
	Teacher-directed and student- centered teaching theory	5
Teaching model	Brief introduction of the text teaching model	5
	Linear and multi-nuclear principle for selecting teaching contents	5
	Six key steps for the first class of the text teaching	8
	Six key steps for the second class of the text teaching	10
	Vocabulary learning strategies for the Students	10
	Practice and coaching strategies for writing	5
	Three steps for guiding reading	8
	Strategies for raising questions	8
	Strategies for extensive reading	10
	Strategies for extensive writing	10
Core strategies	Analysis methods of teaching goals	5
	Method of creating situations	10
	The Selection of teaching methods	8
	Analysis of the key teaching points and difficult points	4
	Methods of reflection on teaching	8

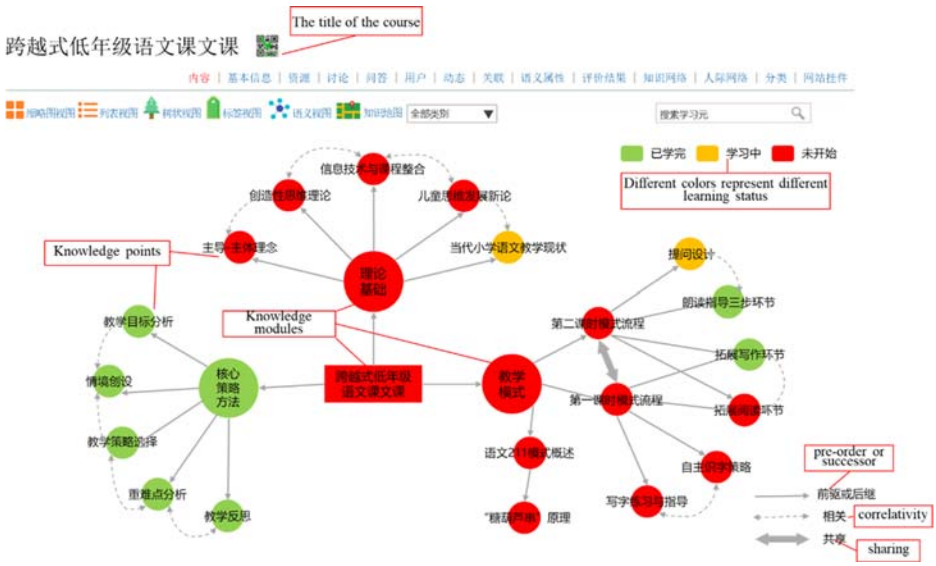

Figure 1. The knowledge map interface of the KM-OML system.

evaluation scheme designed by researchers in advance. In addition, the learning function as well as the system provides all learners with an interaction zone for online communication, and a discussion board for comments and questions.

Research objectives and hypotheses

Based on the above discussion, this study investigates the effect of knowledge map tools on teachers' online micro-learning in relation to their learning engagement, knowledge structure, and learning performance. The hypotheses of this study are as follows:

(1) The learning engagement of learners using the knowledge map tool is better than that of learners not using the map tool.
(2) The knowledge structure of learners using the knowledge map tool is better than that of learners not using it.
(3) The learning performance of learners using the knowledge map tool is better than that of learners not using it.

Methodology

This study adopted a quasi-experimental research method to explore the effectiveness of the KM-OML system in a three-week online micro-learning course conducted using two online learning approaches: learning supported by the knowledge map, and not. The independent variable was the knowledge map tool, and learning engagement, knowledge structure, and learning performance of the participants were the dependent variables.

Participants

The researchers recruited 42 volunteers from seven primary schools in Beijing and Shenzhen, all in-service Mandarin teachers, to participate in the study. To satisfy the requirements of this study, we

Figure 2. The micro-learning interface of the KM-OML system.

developed a pre-test to vet the participants and divided them into two equal groups depending on their scores on the pre-test.

The pre-test questionnaire contained 20 questions in total, covering four aspects: basic personal information (e.g. years of teaching), information technology literacy (e.g. "How to insert video in PPT"), basic knowledge of this course (e.g. "Which of the following teaching modes are suitable for Mandarin lessons"), and teaching knowledge (e.g. "Which of the following elements are included in the information instructional design"). The Cronbach's α value of the questionnaire administered was 0.79, showing acceptable reliability in internal consistency.

During an evaluation of the pre-test, we found that most teachers had little knowledge of the course but enough Information Technology literacy to learn online, which met the requirements of this experiment. Specifically, all teachers scored between 20 and 45 points out of 100, with particularly low scores in knowledge of the course contents. After our evaluation, the teachers were divided into two groups with an equal mean score: namely, an experimental group (group 1; average age:29.2, average teaching age:6.4) and a control group (group 2;average age:27.7, average teaching age:5.6).

Experimental procedure

In this study, the teachers in both groups were required to finish the 20 knowledge points. At the end of the course, all participants were asked to submit a conceptual map, to show what they had learned to reflect the level of construction of their knowledge, and an instructional design scheme applying the theories and pedagogies they had learned in the course into a practical teaching environment.

During the learning process, all teachers were allowed to choose any knowledge point to learn based on their personal preferences, or to learn sequentially through the presented order of the modules and topics. The difference was that the knowledge points and their relationships were presented in two forms between two groups. The experimental group was allowed to access the knowledge map tool while in the control group, the knowledge points were presented in the conventional list-type form. More importantly, the knowledge map could be used to remind the teachers of their personal learning process by presenting different colors of knowledge points and the relationships among them. To ensure the accuracy and reliability of the experiment, the two groups learned the same materials, conducted the same online activities, and were instructed by the same expert.

After the experiment, the differences between the groups were analyzed according to the online learning data recorded by the system automatically and the work submitted by the participants. The online learning data were used to estimate the teachers' learning engagement, and the conceptual map was used to assess their knowledge structure in the course. To assess the teachers' learning performance, the instructional design scheme was evaluated and graded by three experts.

Three teachers in the experimental group accepted our invitation to participate in a semi-structured interview to further explain their personal experience of using a knowledge map compared with their past online learning experience without knowledge maps. The audio for the interviews was recorded and transcribed by researchers for analysis. Informed consent was obtained from all participants. Based on the quantitative and qualitative data, the influence of knowledge map on teachers' learning was comprehensively analyzed.

Instruments

Learning engagement test

To evaluate learning engagement, and considering that the importance of the 20 knowledge points might have differed, the analytic hierarchy process (AHP) (Saaty & Vargas, 2012), was used to determine the weights of the knowledge points (as shown in Table 2). To enhance the reliability of the test, three experts with extensive relevant experience, who had taught the online course, compared the importance of the knowledge points in pairs and developed overall priorities for ranking them separately. Based on the ranking of importance given by the experts, the Yaahp 7.5 automatically calculated the weight of each knowledge point, which is shown in Table 2. After calculation, it was found that the consistency radio of the judgment matrices given by the three experts were all less than 0.1, which satisfied AHP's consistency requirement, indicating that the weights assigned by each expert were reliable.

In terms of evaluating learning engagement, we focus on cognitive engagement and behavioral engagement. Hence, on the data collection, there were learning activities in addition to the online learning time, including learning tasks, exercises, votes, online discussions, and postings of questions. Similarly, to evaluate the teachers' learning engagement with each knowledge point, we used the same method to develop the weight of each aspect of the knowledge points. For example, for the knowledge point "children's new thinking development theory," the participant's learning engagement was evaluated over four dimensions: online learning time, completion of learning tasks, completion of online exercises, and posting questions and comments on the discussion board (see Table 3). Moreover, all data for the four dimensions were recorded and evaluated automatically by the learning system. For example, for online learning time, the participants were

Table 2. The weights of the knowledge points.

Modules	Knowledge points	Weight factors	The total weights
Core theories	Problems and current situations in Mandarin teaching	4.0%	23%
	Children's new thinking development theory	5.0%	
	Integration theory of ICT into Mandarin teaching	5.0%	
	Theory of creative thinking development in Mandarin teaching	5.0%	
	Teacher-directed and student-centred teaching theory	4.0%	
Teaching model	Brief introduction of the teaching model	4.0%	56%
	Linear and multi-nuclear principle for selecting teaching contents	4.0%	
	Six key steps for the first class of the text teaching	8.0%	
	Six key steps for the second class of the text teaching	8.0%	
	Literacy strategies for the students	5.0%	
	Practice and coaching strategies for writing	5.0%	
	Three steps for guiding reading	5.0%	
	Strategies for raising questions	5.0%	
	Strategies for extensive reading	6.0%	
	Strategies for extensive writing	6.0%	
Core strategies	Analysis methods of teaching goals	4.0%	21%
	Method of creating situation	5.0%	
	The Selection of Teaching Methods	4.0%	
	Analysis of the key teaching points and difficult points	4.0%	
	Methods of Reflection on Teaching	4.0%	

automatically graded if they learned for longer than eight minutes online, but not if they did not. Likewise, the other three dimensions were scored by points in the same way. Finally, the final scores of the learning engagement of every participant were automatically calculated and displayed by the KM-OML system.

Evaluation of knowledge structure based on conceptual maps

This study used the framework proposed by Ruiz-Primo and Shavelson (1996) as assessment tool to evaluate the conceptual maps. The framework consisted of (a) a task that invites participants to provide evidence bearing on their knowledge in a domain, (b) a format for the participants' response, and (c) a scoring system by which participants' conceptual maps can be evaluated accurately and consistently. Based on this framework, and the concept map-evaluating system designed by Novak et al. (1984), we built a scoring system for the conceptual maps used in this study (Table 4). Participants were asked to draw the concept map that included entire course, not just a unit or a knowledge point. An example of a concept map was shown in Figure 3.

Evaluation of learning performance based on instructional design scheme

To evaluate the teachers' learning performance, all of them were asked to submit an instructional design scheme at the end of the course. Li and Ma (2014) have proposed an evaluation framework

Table 3. The evaluation scheme of knowledge point "children's new thinking development theory."

Dimensions	An example of items	Evaluation	Weights factors
Online learning time	The cumulative online learning time is no less than 8 min	Whether learned online more than 8 min (yes or no)	20.0%
The completion of the learning tasks	Watch video and answer the following questions: How do you understand "Language is the material form of thought"	Whether the participants finished all learning tasks (yes or no)	30.0%
The completion of online exercises	Finish online exercises	Whether the participants finished all online exercises (yes or no)	25.0%
Posting questions and comments in discussion board	The frequency of posting: for example, a participant asked in discussion board: how to promote the classroom genuinely communicative in limited class teaching hours?	Whether the participants have ever posted questions and comments (yes or no)	25.0%

Table 4 The concept map scoring system.

Evaluation components	Standards	Score
Hierarchy	Check if this being scored concept map has a clear hierarchy. Check if the lower level is more specific than the upper one.	Every effective level scores 5 points.
Concept	Check if the key words of the concept are effective.	Every effective key word scores 1 point.
Connection	Check if the learner has drawn an arrow between two related concepts. Check if the relationship is authentic.	Every authentic and effective arrow scores 1 point.

for the instructional design scheme for teaching Mandarin consisting of 22 assessment items. As shown in Table 5, based on the main knowledge points of micro-learning, we modified the evaluation framework to develop a new one containing 16 items. The scores of each assessment item were provided by the three experts using a five-point Likert scale ranging from one to five.

Results and analysis

Using the pre-set evaluation framework, learning engagement was assessed by the learning system based on the online behaviors of the teachers. The learners' knowledge structure and learning performance were evaluated according to their conceptual maps and instructional design schemes, respectively. As determined by a series of independent sample *t*-tests, the differences between the experimental group and the control group in terms of learning engagement, knowledge structure, and learning performance were analyzed.

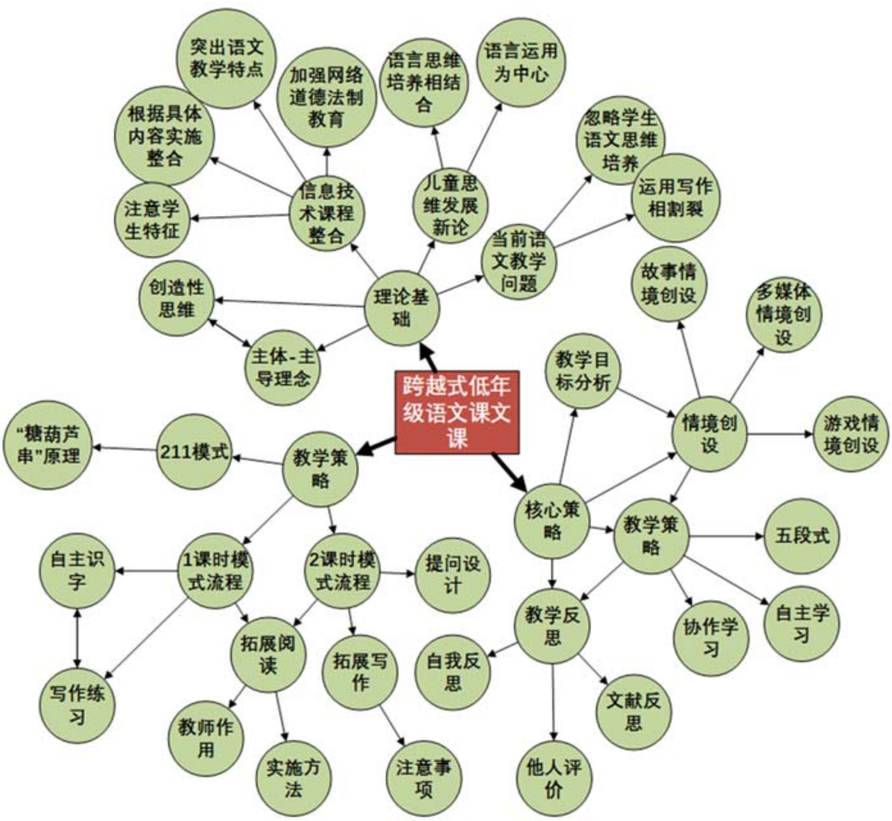

Figure 3. The example of a concept map that covers the entire course.

Table 5. The framework for instructional design diagnosis.

Dimensions	Assessment items	Weights (%)
Front-end analysis	Analyze learners	3
	Identify and describe the learning goals	3
	Identify and describe the learning content, especially the important and difficult learning point	3
	Describe the core pedagogy or teaching ideas	4
Learning process design	Design appropriate learning context and lead into learning fluently	4
	Set or post appropriate tasks/questions/problems	12
	Design rich, interesting and effective learning activities that can promote the learning attitude and deep learning of the students	6
	Select or develop effective strategies for guiding the students reading, such as role play, teacher modeling et al.	9
	Select or develop strategies for promoting the students to grasp the method of literacy learning, especially on writing	9
	Select or develop rich materials for extensive reading that focused on the learning goals	8
	Set effective and proper writing items, provide relative scaffold for writing	8
Pedagogies and teaching ideas	Use the 2-1-1 teaching approach (20 min for learning the textbook, 10 min for extensive reading and 10 min for composition writing)	6
	Integrate the literacy, reading and writing together appropriately	5
	Notice the role of the teacher and the students (students as principal part of the learning, teachers as the assistant and supporter for the students)	5
	Develop the students' creative thinking in language learning	7
	Develop the students' critical thinking in language learning	8

Analysis of learning engagement

To explore differences in learning engagement between the groups, the teachers' learning engagement was analyzed by using a *t*-test based on the learning engagement test. Table 6 shows the averages, standard deviations, and *p*-values of the learning engagement test. There were significant differences between the groups ($t = 2.72$, $p = .013 < .05$, Cohen's $d = 0.84$), where the experimental group outperformed the control group on the list-type materials. Cohen (1988) has claimed that a Cohen's d value greater than 0.5 represents a medium effect size while a value greater than 0.8 represents a large one. The result in Table 6 indicates a good effect size.

Analysis of knowledge structure

The three experts evaluated the conceptual maps submitted by the participants based on certain criteria. The scores were recorded by averaging the scores assigned by them and passed the consistency test ($p = .000 < 0.05$). The final score of each participant was analyzed by a *t*-test. Table 7 shows the averages, standard deviations, and *p*-values for the knowledge structure. There were significant differences between the groups ($t = 6.40$, $p = .000 < .001$, Cohen's $d = 1.98$). As shown in Table 7, the experimental group outperformed the control group. Cohen's d value also indicates a good effect size.

Analysis of learning performance

According to the scale of evaluation of the instructional design scheme, the three experts evaluated submissions by the 42 teachers. The evaluation processes were kept anonymous.

Table 6. Summary of *t*-test analysis for the learning engagement of the two groups.

	N	Mean	SD	*t*	*d*
Experimental group	21	90.61	3.12	2.72*	0.84
Control group	21	81.01	15.87		

*$p < .05$.

Table 7. Summary of *t*-test analysis for knowledge structure of the two groups.

	N	Mean	SD	*t*	*d*
Experimental group	21	83.43	13.92	6.40***	1.98
Control group	21	54.81	15.04		

***$p < .001$.

Kendall's coefficient of concordance of the three experts was 0.626 and the significant probability for the χ^2 test was 0.02 (<0.05). There was considerable consistency in the three experts' scores. The learning performance results are the average of the instructional design schemes scored by experts.

The scores of the two groups were also analyzed by a *t*-test. Table 8 shows the averages, standard deviations, and *p*-values of the assessment of the instructional design scheme. The experimental group using the knowledge map tool outperformed the control group, which did not use it. There was a significant difference between the groups ($t = 3.37$, $p = .002 < .01$, Cohen's $d = 1.04$), and Cohen's *d* value showed a good effect size.

Results of interviews

To further understand the teachers' experiences of using the knowledge map tool compared with previous online learning without it, we conducted semi-structured interviews after the three-week micro-learning course based on grounded theory (Glaser & Strauss, 1967) to analyze the interview data. Grounded theory features of several key analytical strategies: (1) Coding: Categorize the qualitative data, and describe the implications and details of each category. The coding framework is shown in Table 9. (2) Memoing: Record the thinking and ideas of researchers through the entire research process. (3) Summarizing and generalizing: Compile all details and verify the most crucial factor to help understand the data. According to Glaser and Strauss (1967), through the interviews, we were able to infer the key factors of knowledge map-based micro-learning that influenced learning engagement, knowledge structure, and perceptions and learning performance.

Considering the educational background, teaching age, age and gender, this study selected three participants for interview. The basic information of the interviewees is shown in Table 10.

The questions asked in the interview are as follows:

(1) Have you ever used the knowledge map before? If yes, have you gained any new insight into the knowledge map?
(2) Can you briefly describe a time when you used the knowledge map? In general, how would you arrange the order of studying and reviewing the knowledge points when using the knowledge map? When did you usually use the knowledge map during the learning process?
(3) How do you think the knowledge map can influence your online learning? How is it different from your previous online learning experience?
(4) Do you think this learning approach fits you?
(5) Do you think this tool can help you learn? For example, does it make the relationship between knowledge points clear? Does it help you understand the position of the learning points in the overall learning system? Do you still remember the learning contents and the map (two weeks after the conclusion of the course)?

Table 8. Summary of the *t*-test analysis of instructional design plans of the two groups.

	N	Mean	SD	*t*	*d*
Experimental group	21	86.55	3.27	3.37**	1.04
Control group	21	82.64	4.18		

**$p < .01$.

Table 9. Coding framework and counting statistics of interviews.

Code level 1	Code level 2	Count
Attitude and experience of knowledge map	Positive attitude	3
	Negative attitude	0
Perception of the learning effect	Learning depth	1
	Promote reflection	1
	Knowledge internalization	2
	Knowledge structure	3
	Effect persistence	2
Feelings on learning process	Convenience	3
	Flexibility	3

According to the interview data, teachers in the experimental group thought that the best part of learning with the knowledge map was that it provided a "clearer and more systematic knowledge structure," "flexible learning plan," made it "easier to engage in learning," and made for a "more relaxed learning experience."

Three of the interviewees claimed that the knowledge map tool helped them understand the knowledge structures and purposes of learning, which made them feel more relaxed when learning. Unlike their past experience, they were supported by the knowledge map tool. It helped them arrange the learning plan, choose the next learning point, and transfer the contents of learning to their instructional practices. They all expressed a preference for this learning approach.

With regard to a "flexible learning plan" and the "ease of engagement in learning," a few interviewees said that they had first reviewed the entire knowledge map, chosen the learning points based on their preferences, and had then considered the logical relationships presented by the map. During the learning process, they had preferred to review the learning points and compare them from time to time, which helped them reflect on the contents.

With regard to the advantages of using the knowledge map tool, the teachers/interviewees claimed that it helped them fully understand the learning system and knowledge structure. It helped them remember the positions, relationships, and meanings of the learning points. When they thought of a learning point, they said, they would think of relevant points at the same time. Moreover, they claimed that the knowledge map tool helped them master the knowledge in a more structured manner that rendered it persistent in memory: They remembered clearly the knowledge map two weeks after the experiment, and expressed belief that this might not have been possible if they had been learning without a clear and well-structured knowledge map.

Discussion and conclusions

Previous research has expressed that micro-learning in conjunction with other approaches may have the potential to improve learning outcomes (Stohr et al., 2019). The study integrated the knowledge map as a navigation and recording tool into the micro-learning processes to allow learners to have the ability to master the knowledge structure and learning contents. The result showed that knowledge map-based online micro-learning not only significantly enhance learning engagement and learning performance, but also facilitates learners to form well-structured knowledge.

Table 10. The basic information of the interviewees.

Number	Gender	Educational background	Teaching age	Age
1	Female	Bachelor	4	28
2	Female	Master	10	32
3	Male	Master	2	24

Learning engagement

The results of this study indicate that the experimental group outperformed the control group in terms of learning engagement (Table 6), helped them learn better and perform better in the assessment, which is consistent with the view of Cheng and Chu (2018). The knowledge map tool had a positive effect on the online micro-learning of in-service teachers, in particular because the clear and systematic knowledge structure of the knowledge map tool helped them understand the learning system and learning objectives. The participants also indicated feeling relaxed about learning. The recording functions of the knowledge map allowed them to visualize the different learning processes of each knowledge point, which helped them formulate the learning order and avoid confusion when exploring the logic of the knowledge points. According to the interviews and quantitative data from the experiment, the participants in the experimental group appeared more relaxed and engaged in the learning process than those in the control group. This result supports research hypothesis 1, and is consistent with findings by Shaw (2010).

Knowledge structure

The findings show that the experimental group outperformed the control group in terms of knowledge structure, and there were significant differences between them. The experimental group did better on the three main aspects of the conceptual map: the quantity and quality of the concepts, hierarchical structure, and the correctness of the conjunction links. Compared with the control group, the experimental group was able to master the core knowledge concepts and relationships much better with the help of the knowledge map tool. Based on the analysis of the qualitative data, the knowledge map tool can help teachers build a more integral and stable knowledge structure and links between knowledge points. The tool prevented the teachers from getting stuck on a single point. The research of Lv et al. (2016) confirmed that the knowledge map could organize scattered knowledge artifacts and presents them visually in meaningful categorizations. The interviewees also indicate that the knowledge map tool helped them store and recall the structures of knowledge. This result supports research hypothesis 2. Meanwhile, the previous studiy have confirmed micro-learning provides abundant online resources to promote instant learning according to individual needs (Nikou & Economides, 2018; Souza & Amaral, 2014). According to the results of the interview, knowledge map-based online micro-learning has maintained the advantage of micro-learning, which is a flexible learning model that reflects the learners' personal needs.

Learning performance

Based on the quantitative and qualitative data in this study, the knowledge map can be viewed as a useful tool to enhance teachers' learning performance. For instance, the evaluation of the instructional design schemes showed that the average score of the experimental group was higher than that of the control group. According to the results of the interviews, the knowledge map clearly presented logical relationships between knowledge points and linked the corresponding learning resources, which was conducive to reflection and purposeful reviews by the teachers learning. Because personal knowledge forms the basis of subsequent knowledge construction (Novak, 1990), the knowledge map can promote their reflection and internalization to some extent. Recent researches have indicated that knowledge maps make it easy for learners to digest complex knowledge content in a short time (Hwang et al., 2018), which may explain the above results. However, based on anecdotal reasoning, other factors may affect the quality of the knowledge construction and creation. Previous studies have indicated that such results may derive from other factors, such as the participants' prior teaching knowledge, their knowledge transference ability, or different learning styles that may be predominantly visual or verbal learning preferences (Sung & Hwang, 2013).

Limitation and future

In the course of our research, based on the researchers' observations, we found that teachers with more than two years of teaching experience exhibited clear advantages in the test results of the teaching instructional scheme than teachers whose teaching experience was shorter than two years. The reason for this threshold of experience, and the influence of the number of years of teaching on a teacher's knowledge construction and creation, is a direction of our future research on the subject. Due to limitations relating to the sample size and scope of research, we interviewed only three Mandarin teachers from the experimental group. Future studies can also further expand the sample size. In addition, it is worth further exploring the reflections of teachers from the control group to gain a more precise comparison of approaches to learning, and further clarifying how knowledge maps affect online learning. Although the many advantages of knowledge maps as teaching aids can be recognized, the specifics and details of the factors affecting learning should be examined in future research.

Acknowledgements

This research was funded by the "Research on Time-Emotion–Cognition Analysis Model and Automatic Feedback Mechanism of Online Asynchronous Interaction" project (No. 62077007), supported by National Natural Science Foundation of China, and the "Building Teacher Community Knowledge of Blended Learning: An Online Collaborative Approach, with a Focus on Developing Project-Based Learning" project, supported by Advanced Innovation Center for Future Education (AICFE), Beijing Normal University, China.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was funded by the "Research on Time-Emotion-Cognition Analysis Model and Automatic Feedback Mechanism of Online Asynchronous Interaction" project (No. 62077007), supported by National Natural Science Foundation of China, and the "Building Teacher Community Knowledge of Blended Learning: An Online Collaborative Approach, with a Focus on Developing Project-Based Learning" project, supported by Advanced Innovation Center for Future Education (AICFE), Beijing Normal University, China.

Notes on contributors

Ning Ma is an associate professor at the School of Educational Technology, Faculty of Education and Advanced Innovation Center for Future Education, Beijing Normal University. Her research interests include technology-enhanced learning, online learning analysis, STEM and technology-enhanced teacher professional development.

Fei-long Zhao is a Master student at the school of Educational Technology, Beijing Normal University. His research interests include digital learning and teacher professional development.

Peng-Qin Zhou is a Master student at the school of Educational Technology, Beijing Normal University. Her research interests include technology enhanced learning, computer-assisted learning.

Jun-Jie is a Master student at the school of Educational Technology, Beijing Normal University. His research interests include teacher professional development and technology enhanced learning.

Lei Du is a postgraduate student at the School of Educational Technology, Faculty of Education, Beijing Normal University. Her research interests include digital learning, STEM and teacher professional development.

ORCID

Ning Ma http://orcid.org/0000-0002-1941-724X

References

Al-Dmour, A., Gasaymeh, A. M., Abuhelaleh, M., & Almi'ani, M. (2017). Effects of concept map approach on students' attitude and motivation towards documenting computing capstone projects. *International Journal of Technology Enhanced Learning*, *9*(1), 70–79. https://doi.org/10.1504/IJTEL.2017.084069

Brita-Paja, J. L., Gregorio, C., Llana, L., Pareja, C., & Riesco, A. (2019). Introducing MOOC-like methodologies in a face-to-face undergraduate course: A detailed case study. *Interactive Learning Environments*, *27*(1), 15–32. https://doi.org/10.1080/10494820.2018.1451345

Chang, J. H., Chiu, P. S., & Huang, Y. M. (2018). A sharing mind map oriented approach to enhance collaborative mobile learning with digital archiving systems. *The International Review of Research in Open and Distributed Learning*, *19*(1), 1–24. https://doi.org/10.19173/irrodl.v19i1.3168

Chen, Y., Chen, N. S., & Tsai, C. C. (2009). The use of online synchronous discussion for web-based professional development for teachers. *Computers & Education*, *53*(4), 1155–1166. https://doi.org/10.1016/j.compedu.2009.05.026

Chen, M., Chiang, F. K., Jiang, Y. N., & Yu, S. Q. (2016). A context-adaptive teacher training model in a ubiquitous learning environment. *Interactive Learning Environments*, *25*(1), 113–126. https://doi.org/10.1080/10494820.2016.1143845

Cheng, L. C., & Chu, H. C. (2018). An innovative consensus map-embedded collaborative learning system for er diagram learning: Sequential analysis of students' learning achievements. *Interactive Learning Environments*, *27*(3), 410–425. https://doi.org/10.1080/10494820.2018.1482357

Cho, M. H., & Rathbun, G. (2013). Implementing teacher-centred online teacher professional development (oTPD) programme in higher education: A case study. *Innovations in Education and Teaching International*, *50*(2), 144–156. https://doi.org/10.1080/14703297.2012.760868

Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd). New York: Routledge. https://doi.org/10.4324/9780203771587

Fu, Q. K., Lin, C. J., Hwang, G. J., & Zhang, L. (2019). Impacts of a mind mapping-based contextual gaming approach on EFL students' writing performance, learning perceptions and generative uses in an English course. *Computers & Education*, *137*, 59–77. https://doi.org/10.1016/j.compedu.2019.04.005

Glaser, B., & Strauss, A. (1967). The Discovery of Grounded Theory: Strategies for Qualitative Research.Mill Valley. CA: Sociology Press.

Gore, J., Lloyd, A., Smith, M., Bowe, J., Ellis, H., & Lubans, D. (2017). Effects of professional development on the quality of teaching: Results from a randomized controlled trial of quality teaching rounds. *Teaching and Teacher Education*, *68*, 99–113. https://doi.org/10.1016/j.tate.2017.08.007

Hou, H. T., Yu, T. F., Wu, Y. X., Sung, Y. T., & Chang, K. E. (2016). Development and evaluation of a web map mind tool environment with the theory of spatial thinking and project-based learning strategy. *British Journal of Educational Technology*, *47*(2), 390–402. https://doi.org/10.1111/bjet.12241

Hung, C. M., Hwang, G. J., & Wang, S. Y. (2014). Effects of an integrated mind-mapping and problem-posing approach on students' in-field mobile learning performance in a natural science course. *International Journal of Mobile Learning and Organisation*, *8*(3), 187–200. https://doi.org/10.1504/IJMLO.2014.067019

Huo, C. Q., & Shen, B. G. (2015). Teaching reform of English listening and speaking in China based on mobile micro-learning. *Creative Education*, *6*(20), 2221–2226. https://doi.org/10.4236/ce.2015.620228

Hwang, G. J., Chen, M. R. A., Sung, H. Y., & Lin, M. H. (2018). Effects of integrating a concept mapping-based summarization strategy into flipped learning on students' reading performances and perceptions in Chinese courses. *British Journal of Educational Technology*, *50*(5), 2703–2719. https://doi.org/10.1111/bjet.12708

Hwang, G. J., Li, X. Y., & Chen, C. H. (2019). Lessons learned from integrating concept mapping and gaming approaches into learning scenarios using mobile devices: Analysis of an activity for a geology course. *International Jorunal of Mobile Learning and Organisation*, *13*(3), 286–308. https://doi.org/10.1504/IJMLO.2019.100412

Jomah, O., Masoud, A. K., Kishore, X. P., & Aurelia, S. (2014). Micro learning: A modernized education system. *Brain-Broad Research in Artificial Intelligence and Neuroscience*, *7*(1), 103–110.

Kennedy, M. M. (2016). How does professional development improve teaching? *Review of Educational Research*, *86*(4), 945–980. https://doi.org/10.3102/0034654315626800

Koh, J. H. L. (2019). TPACK design scaffolds for supporting teacher pedagogical change. *Educational Technology Research and Development*, *67*(3), 577–595. https://doi.org/10.1007/s11423-018-9627-5

Lee, J. H., & Segev, A. (2012). Knowledge maps for e-learning. *Computers & Education*, *59*(2), 353–364. https://doi.org/10.1016/j.compedu.2012.01.017

Li, J., & Ma, N. (2014). The personalized online training model based on the diagnoses of the teachers, instructional plan. *China Educational Technology*, *01*, 114–118.

Lindvall, J., & Ryve, A. (2019). Coherence and the positioning of teachers in professional development programs: A systematic review. *Educational Research Review*, *27*, 140–154. https://doi.org/10.1016/j.edurev.2019.03.005

Lv, Y., Zhao, G., & Yu, Y. (2016). A novel method for adaptive knowledge map construction in the aircraft development. *Multimedia Tools and Applications*, *75*(24), 17465–17486. https://doi.org/10.1007/s11042-015-3113-4

Ma, N., Du, L., Zhang, Y. L., Cui, Z. J., & Ma, R. (2020). The effect of interaction between knowledge map and collaborative learning strategies on teachers' learning performance and self-efficacy of group learning. *Interactive Learning Environments*. https://doi.org/10.1080/10494820.2020.1855204

Mutodi, P., & Chigonga, B. (2016). Concept map as an assessment tool in secondary school mathematics: An analysis of teachers' perspectives. *Eurasia Journal of Mathematics, Science & Technology Education*, *12*(10), 2685–2696. https://doi.org/10.12973/eurasia.2016.2301a

Nikou, S. A., & Economides, A. A. (2018). Mobile-based micro-learning and assessment: Impact on learning performance and motivation of high school students. *Journal of Computer Assisted Learning*, *34*(3), 269–278. https://doi.org/10.1111/jcal.12240

Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching*, *27*(10), 937–949. https://doi.org/10.1002/tea.3660271003

Novak, J., Gowin, D., & Kahle, J. (1984). *Learning how to learn*. Cambridge University Press. https://doi.org/10.1017/CBO9781139173469.

O'Donnell, A. M., Dansereau, D. F., & Hall, R. H. (2002). Knowledge maps as scaffolds for cognitive processing. *Educational Psychology Review*, *14*(1), 71–86. https://doi.org/10.1023/A:1013132527007

Parsons, S. A., Hutchison, A. C., Hall, L. A., Parsons, A. W., Ives, S. T., & Leggett, A. B. (2019). U.S. teachers' perceptions of online professional development. *Teaching and Teacher Education*, *82*, 33–42. https://doi.org/10.1016/j.tate.2019.03.006

Powell, C. G., & Bodur, Y. (2019). Teachers' perceptions of an online professional development experience: Implications for a design and implementation framework. *Teaching and Teacher Education*, *77*, 19–30. https://doi.org/10.1016/j.tate.2018.09.004

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching*, *33*(6), 569–600. https://doi.org/10.1002/(SICI)1098-2736(199608)33:6<569::AID-TEA1>3.0.CO;2-M

Saaty, T. L., & Vargas, L. G. (2012). *Models, methods, concepts & applications of the analytic hierarchy process (International series in operations research & management science)*. Springer, 175, 1–20.

Shaw, R. (2019). The learning performance of different knowledge map construction methods and learning styles moderation for programming language learning. *Journal of Educational Computing Research*, *56*(8), 1407–1429. https://doi.org/10.1177/0735633117744345

Shaw, R. S. (2010). A study of learning performance of e-learning materials design with knowledge maps. *Computers & Education*, *54*(1), 253–264. https://doi.org/10.1016/j.compedu.2009.08.007

Slemmons, K., Anyanwu, K., Hames, J., Grabski, D., Mlsna, J., Simkins, E., & Cook, P. (2018). The impact of video length on learning in a middle-level flipped science setting: Implications for diversity inclusion. *Journal of Science Education and Technology*, *27*(5), 469–479. https://doi.org/10.1007/s10956-018-9736-2

Souza, M. I. F., & Amaral, S. F. (2014). Educational microcontent for mobile learning virtual environments. *Creative Education*, *05*(9), 672–681. https://doi.org/10.4236/ce.2014.59079

Stohr, C., Stathakarou, N., Mueller, F., Nifakos, S., & McGrath, C. (2019). Videos as learning objects in MOOCs: A study of specialist and non-specialist participants' video activity in MOOCs. *British Journal of Educational Technology*, *50*(1), 166–176. https://doi.org/10.1111/bjet.12623

Sung, H. Y., & Hwang, G. J. (2013). A collaborative game-based learning approach to improving students' learning performance in science courses. Computers & Education , *63*(1), 43–51. https://doi.org/10.1016/j.compedu.2012.11.019

Yang, M., Shao, Z., Liu, Q., & Liu, C. (2017). Understanding the quality factors that influence the continuance intention of students toward participation in MOOCs. *Educational Technology Research and Development*, *65*(5), 1195–1214. https://doi.org/10.1007/s11423-017-9513-6

Zhang, Q., Peck, K. L., Hristova, A., Jablokow, K. W., Hoffman, V., Park, E., & Bayeck, R. Y. (2016). Exploring the communication preferences of mooc learners and the value of preference-based groups: Is grouping enough? *Educational Technology Research and Development*, *64*(4), 809–837. doi:10.1007/s11423-016-9439-4