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Development of a mobile learning system based on a collaborative problem-posing strategy

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In this study, a problem-posing strategy is proposed for supporting collaborative mobile learning activities. Accordingly, a mobile learning environment has been developed, and an experiment on a local culture course has been conducted to evaluate the effectiveness of the proposed approach. Three classes of an elementary school in southern Taiwan participated in the experiment. One class was the experimental group who learned with the problem-posing-based mobile learning approach, while the other two classes were the control groups who learned with the conventional mobile learning approach and the traditional problem-posing approach, respectively. The experimental results show that the new approach not only improved the students' learning achievement, but also promoted their local culture identity and group learning self-efficacy.

Keywords: mobile learning; problem-posing strategy; QR code; context awareness

Introduction

The advances in computer and network technologies have encouraged researchers to develop new strategies or tools for various educational purposes, including teaching supports, assessments and learning supports (Dreyer & Nel, 2003; Latchman, 1999). Such technology-enhanced learning approaches have been reported as being promising in terms of improving students' learning performance as well as helping teachers manage and analyze students' learning portfolios (Dornan, Carroll, & Parboosingh, 2002; Liu, 2007; Pegrum, Oakley, & Faulkner, 2013). On the other hand, educators have indicated the importance and requirement of situating students in real-world learning environments for problem-solving practice (Brown, Collins, & Duguid, 1989; Hsieh, Jang, Hwang, & Chen, 2011; Wenger, 1997; Wu, Hwang, Su, & Huang, 2012), implying the necessity and challenge of engaging students in a series of designed activities that combine both real-world and digital-world learning resources (Hwang, Tsai, & Yang, 2008).

The rapid advancement and popularity of mobile and wireless communication technologies have provided good opportunities for developing learning environments to accomplish such technology-enhanced real-world learning (Cheon, Lee, Crooks, & Song, 2012; Rogers et al., 2005; So, Kim, & Looi, 2008); that is, students are situated in

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the real-world scenarios with access to digital resources via mobile devices and wireless communication networks, which has been called mobile or ubiquitous learning by researchers (Laru, Jarvela, & Clariana, 2012; Sharples, Corlett, & Westmancott, 2002; Wong, Chin, Tan, & Liu, 2010).

Several researchers have reported the benefits of applying mobile and wireless communication technologies to various in-field learning activities, in which students are situated in specific fields, such as ecology areas, laboratories, museums, school campuses and places of historic interest, for observations, investigations, data collection or practice (Huang, Jang, Machtmes, & Deggs, 2012; Ogata, Matsuka, El-Bishouty, & Yano, 2009; Shih, Hwang, Chu, & Chuang, 2011). For example, Hung, Lin, and Hwang (2010) conducted a field trip in a wetland for ecology observations using mobile devices with wireless communications to provide learning supports and supplementary materials; Wong, Chen, and Jan (2012) employed a mobile-assisted Chinese language learning approach that encouraged students to take photos of real-life contexts related to Chinese idioms or conjunctions and share the sentences they made based on the contexts on wiki.

In the meantime, researchers have indicated the benefits of using location-aware technologies, such as radio frequency identification (RFID) or quick response code (QR code), in enabling the learning system to provide the right information in the right place and at the right time during field trips (Chen & Li, 2009; FitzGerald, 2012; Hwang et al., 2008). Accordingly, several studies have attempted to use mobile, wireless communication and sensing technologies to conduct in-field learning activities. For example, Wu et al. (2012) developed a learning environment to guide nursing-school students to practice nursing skills using mobile devices equipped with wireless communication and RFID equipment. Moreover, several studies related to the use of those technologies in supporting collaborative learning have been reported (Ryu & Parsons, 2012; Sanchez & Olivares, 2011; Timmis, 2012). For example, Charitonos, Blake, Scanlon, and Jones (2012) conducted a collaborative mobile learning activity in a museum, and found that field learning experiences could promote online peer interactions. In a collaborative learning activity, students are grouped to learn in teams. The members in a team have common goals and learning tasks, which encourage them to solve problems or complete learning tasks via discussion and knowledge sharing (Brown et al., 1989; von Glasersfeld, 1995).

While many applications have revealed the benefit of mobile learning in situating students in authentic learning scenarios and that of collaborative learning in promoting peer interactions, researchers have indicated the need for proper learning supports to help students think in-depth and have discussions based on what they are learning (Chu, Hwang, & Tsai, 2010; Luchini, Bobrowsky, Curtis, Quintana, & Soloway, 2002; Sung & Hwang, 2013). Hwang, Wu, Tseng, and Huang (2011) further indicated that most students might fail to organize what they have observed or learned in the field without learning guidance or support when facing such an information-rich environment that combines real-world and digital-world learning materials. Therefore, researchers have suggested the importance and necessity of developing effective learning strategies or tools to assist students in organizing what they have learned from the field as well as from their textbooks (Paige & Daley, 2009).

To cope with this problem, a three-stage problem-posing-based mobile learning approach is proposed for conducting in-field collaborative learning activities. Moreover, an experiment on an elementary-school local culture course has been conducted to evaluate the performance of the proposed approach by investigating the following research questions:

(1) Can the collaborative problem-posing-based mobile learning approach improve the students' learning achievements in comparison with conventional collaborative mobile learning and traditional collaborative learning?
(2) Can the collaborative problem-posing-based mobile learning approach improve the students' local culture identity (i.e. their affection for and perceived belonging to the local culture) in comparison with conventional collaborative mobile learning and traditional collaborative learning?
(3) Can the collaborative problem-posing-based mobile learning approach promote the students' self-efficacy of group learning (i.e. their beliefs in the learning group's ability to complete tasks and reach goals) in comparison with conventional collaborative mobile learning and traditional collaborative learning?

Literature review

Problem posing has been recognized as a significant component of various curricula. It involves the generation of new problems related to an issue or situation, including identifying the key elements of a problem and how they relate to the learning objective (English, 1997). In the past decades, problem-solving strategies have been applied to the learning activities of various courses. For example, Casagrande et al. (1998) employed a problem-posing strategy in the practice of health professionals and found it adequate for application in several modalities of health-care settings, in particular, in nursing training. Several previous studies have also suggested that engaging in the problem-posing process could benefit students in terms of their cognitive growth (Brindley & Scoffield, 1998; Purchase, 2000). A theoretical account of why the learning process would benefit from problem posing is the self-explanation theory proposed by Chi, Bassok, Lewis, Reimann, and Glaser (1989). They have indicated that effective learning occurs when students try to refine and expand the conditions for parts of the cases or examples in the learning content to generate self-explanations or extended problems. Hsu and Tsai (2013) have further confirmed this point by integrating self-explanation into a computer game.

Recent advancements in computer and network technologies have encouraged researchers to develop computer-based or web-based learning systems to facilitate students' learning and practice (Zhang, Cooley, & Ni, 2001). Yu, Liu, and Chan (2004) indicated that, in such drill-and-practice systems, students can only respond to questions proposed by teachers. They further indicated that it would benefit students more if the learning systems enabled and encouraged students to pose questions based on the knowledge or concepts that they have learned and which they perceive as being important and worth discussing.

In recent years, some researchers have attempted to develop problem-posing systems to help learners organize their knowledge and make reflections during the learning process (Hirashima, Yokoyama, Okamoto, & Takeuchi, 2008). For example, Chang (2007) and Chang, Wu, Weng, and Sung (2012) developed problem-posing systems for mathematics courses. Both studies reported that such an approach could help the students concentrate more on what they were learning, and gain better problem-posing abilities.

On the other hand, several studies have reported the difficulties of applying such learning strategies that engage students in higher-order thinking (Hwang & Chang, 2011); for example, some students might have difficulties posing problems if they do not have sufficient knowledge, experience or ability in identifying the key elements of the learning objectives or linking what they are learning to their prior knowledge. Consequently, it is important to provide learning supports during the problem-posing activities, in particular, for elementary-school students who have less experience in identifying problems and raising questions. Among various learning approaches, collaborative learning has been reported as a promising approach that helps students cope with difficult learning tasks via peer interactions (Wang & Hwang, 2012). For example, Crespo (2003) adapted a problem-posing strategy in a mathematics course to investigate changes in preservice teachers' practices, and found that posing problems enabled the teachers to cooperate and have opportunities to explore new kinds of problems. Kontorovicha, Koichua, Leikinb, and Berman (2012) further emphasized the importance of conducting problem-posing activities in small groups. In this study, a problem-posing strategy is proposed for developing a mobile learning system for guiding students to learn in the field collaboratively. An experiment on an elementary-school local culture course was conducted to demonstrate the effectiveness of the proposed approach.

Mobile learning system with a collaborative problem-posing strategy

In this study, a collaborative mobile learning system based on a problem-posing strategy is developed, consisting of a "key element identification" phase and a "problem-posing-guiding" phase. After logging into the learning system, the students are guided to find a set of learning targets in small groups. When a group of students arrives at the location of a learning target, the system asks the students to confirm their location by using their smartphones to scan the QR code on the target. After confirming the location of the group, the learning system presents the learning tasks and supplementary materials to the students. Following that, a series of questions is presented to the students to guide them to observe and identify the key elements of the learning target. If the students correctly answer the questions, an assistance procedure is invoked to guide them to pose questions, as shown in Figure 1.

In the "key element identification" phase, the mobile learning system guides the students to individual learning targets in the field, and presents a series of questions and the corresponding supplementary materials to guide them to identify key elements related to the learning targets, as shown in Figure 2. If the students fail to correctly answer the questions the first time, the system will give some hints to guide them to make further observations and read the supplementary materials. If the students fail to answer correctly again, the system will then present the correct answers to them. This phase is designed based on the concept indicated by educators that students need to identify the key elements of a problem and the relevance of the elements to the learning objective before posing questions (English, 1997).

The problem-posing-guiding strategy consists of three stages. In the first stage, some clues related to the learning targets, such as the characteristics, background history and ancient customs of the local culture artworks, are given to the students to help them raise questions, as shown in the left part of Figure 3. Following that, in the second stage, some question templates, which are generated based on the questions proposed by domain experts (or teachers), are presented to the students. A question template can be viewed as a fill-in-the-blank question in which the key elements are removed from the experts' questions, as shown in the right part of Figure 3. Those templates are used to guide the students to re-consider and modify the problems they have raised. In the third stage, the experts' questions are presented to the students to help them reflect on what they have posed. Such a problem-posing-guiding strategy fits the self-explanation theory proposed by Chi et al. (1989) who attributed the occurrence of effective learning to refining and expanding the conditions for parts of the learning cases or examples to generate

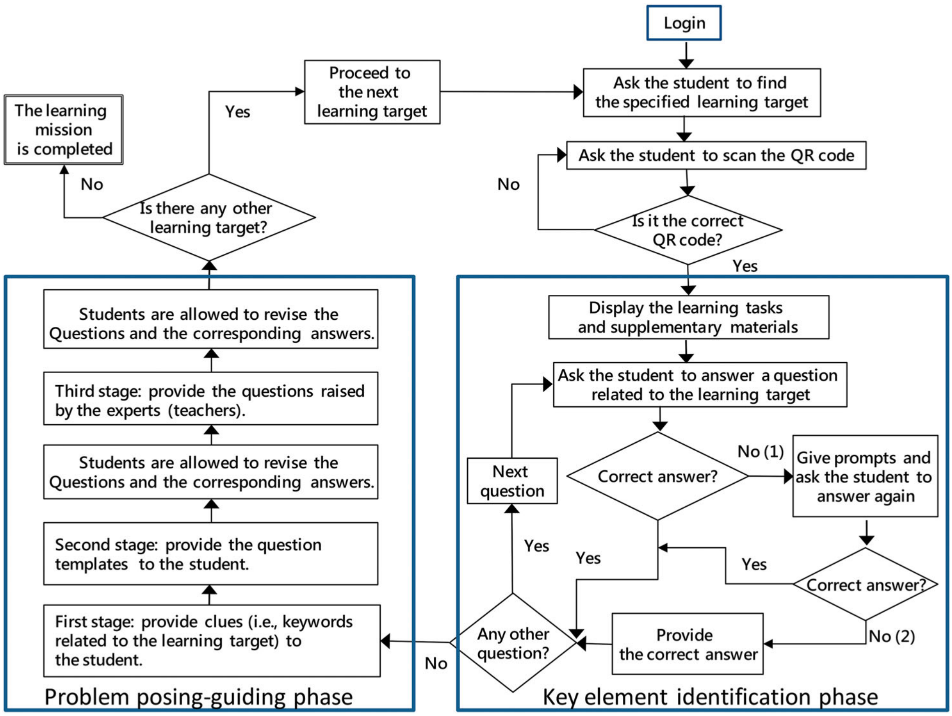

Figure 1. The collaborative problem-posing-based learning guidance mechanism.

self-explanations or extended problems. Moreover, the three prompting stages of the problem-posing-guiding strategy fit the cognitive load theory which emphasizes that human working memory can only handle a limited number of novel interacting elements during the learning process (van Merriënboer & Sweller, 2005; Paas, Renkl, & Sweller, 2003); that is, such a progressive guidance of problem posing could avoid working memory overload, and hence decrease the cognitive load of the students and improve their learning performance.

Figure 2. Illustrative example of guiding the students to observe the learning targets in the field.

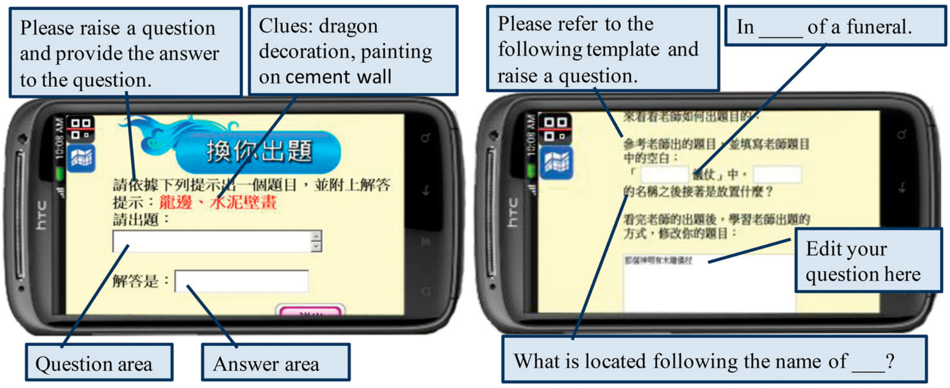

Figure 3. Illustrative example of the problem-posing-guiding mechanism.

Experiment design

To evaluate the effectiveness of the innovative approach, a mobile learning activity was designed for an elementary-school local culture course. The objective of the learning activity was to promote students' affection for the local culture as well as to help them understand the background and meanings of the cultural or historical relics. The learning environment was the Chao-Xing temple in southern Taiwan. The learning targets were the cultural or historical relics in the temple, such as the pillars, statues and steles. An experiment was conducted to compare the learning achievements, self-efficacy and the local culture identity of the students who participated in the problem-posing-based mobile learning system with different learning strategies.

Learning environment

In this mobile learning environment, a local wireless communication network was installed such that the students were able to interact with the mobile learning system during the in-field learning process. The learning content consisted of five main parts, that is, the ancient customs, history, carving art, painted murals and the gods in the temple. Each part consisted of two to five main learning targets, such as the stone-carved lions in the main hall and the long-pan pillars in the front hall, each of which has its own historical story and is related to particular ancient customs.

Participants

The participants of the experiment were three classes of fifth graders in an elementary school in southern Taiwan. A total of 79 students, who were 11 years old on average, participated in this study. One class with 27 students (16 males and 11 females) was assigned to be the experimental group, one class with 26 students (14 males and 12 females) was control group A and the other class with 26 students (14 males and 12 females) was control group B. The three classes were taught by the same instructor who had more than 15 years' teaching experience and had a good reputation as a social studies teacher. In addition, to avoid the Hawthorne effect, visits to the temple of the three groups were arranged at different times in the same week, following the original schedule of the local cultural classes; moreover, the mobile learning environment (i.e. the temple) was set up in the same way for the three groups. Therefore, the students would not know the learning scenarios of the other groups, and the time for conducting the learning activity would not affect their learning results.

Experimental procedure

The experiment was conducted for an elementary-school local culture course, which aimed to guide the students to understand the local cultural history, the transition of local culture and the ancient customs via observing the artworks and the cultural relics in the temple. It was expected that the students would be able to blend harmoniously and grasp thoroughly the history or ancient customs of and the relationships between those learning targets through the learning activity.

Figure 4 shows the procedure of the learning activity, which consists of two learning phases conducted over a period of two weeks. In the first week, in-class learning for the local culture course was conducted. In this phase, the three groups of students were instructed by the same teacher about the basic knowledge of the local culture. Following the instruction, the students took the pre-test and the pre-questionnaires of group learning self-efficacy and local culture identity. The pre-test aimed to evaluate their basic knowledge of the local culture.

In the second week, the in-field learning activity was conducted. At the beginning of this phase, the teacher introduced the Chao-Xing temple and the learning targets in the temple; moreover, a demonstration was given to show them how to use the smartphones and interact with the learning system via scanning the QR codes. During the in-field learning activity, the students learned in small teams. Each learning team consisted of a high-achieving, a middle-achieving and a low-achieving student based on the pre-test scores; that is, a heterogeneous grouping approach was adopted.

The learning activities lasted 120 minutes. Each student in the experimental group and control group A was equipped with a smartphone to interact with the mobile learning system and to access the supplemental materials. The students in the experimental group learned with the collaborative problem-posing-based mobile learning approach. The learning system first guided the members in the same team to the location of each learning target,

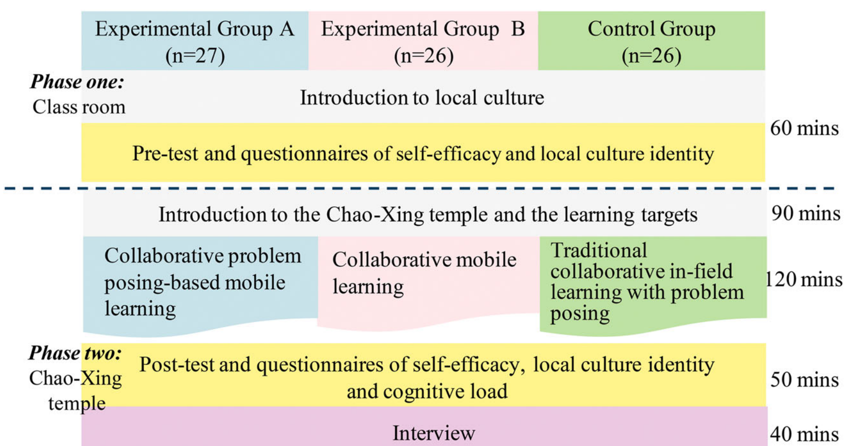

Figure 4. Experimental design of the learning activities.

and then started the observation tasks. The team members were asked to answer a series of questions related to the learning target and submitted their answers after they had agreed on the answers. After the students completed the observation tasks, the learning system started the three-stage question-posing-guiding procedure to assist the students in raising questions based on their observations. As the students in a team were guided to observe the same learning target at the same time, they could discuss in an online or a face-to-face mode during the observation and problem-posing process.

The students in control group A learned with the collaborative mobile learning approach; that is, they were guided by the learning system to collaboratively observe the learning targets and answer a series of questions to complete their learning tasks in groups after discussing and agreeing on the answers. During the learning process, if the students failed to correctly answer the questions, the learning system would guide them to find the comparative learning targets for making comparisons. If the students failed to correctly answer the same questions again, the learning system would provide the supplementary materials to them. Such an approach has been shown to be effective by previous studies (Chu, Hwang, Tsai, & Tseng, 2010).

On the other hand, the students in control group B learned with the traditional collaborative learning approach; that is, they were guided and instructed by the teacher and the printed materials to observe each learning target for completing the printed learning sheet, which asked them to raise questions as well as answer a series of questions prepared by the teacher based on what they had observed and learned in the temple. Following that, the teacher asked the students to share their learning sheets and gave feedback to them accordingly.

After the learning activity, the students were asked to take the post-test and fill out the post-questionnaires for measuring their learning achievements, local culture identity and group learning self-efficacy. Finally, the researchers interviewed the teachers and students to collect their opinions and perceptions of the learning approaches.

Measuring tools

The measuring tools of this study include the pre-test, the post-test and the questionnaires for measuring the local culture identity and group learning self-efficacy.

The pre-test aimed to evaluate whether the three groups of students had an equivalent prior knowledge before participating in the learning activity. It consisted of 15 fill-in-the-blank questions (60%) and 8 short-answer questions (40%) about the basic knowledge of local culture. The post-test consisted of 20 multiple-choice items (40%), 8 short-answer questions (48%) and 2 open-ended questions (12%) for assessing the students' knowledge of differentiating cultural relics and ancient customs. Both the pre-test and post-test were designed by two experts who had more than 10 years' experience of teaching local culture courses.

The local culture identity questionnaire was modified from the questionnaire developed by Hwang and Chang (2011). It consisted of five items using a seven-point Likert scale, such as "I would like to endeavor to preserve and maintain historic and cultural relics" and "I am pleased to participate in local culture activities in my hometown." The Cronbach's α value of the questionnaire was 0.79, showing the high reliability of the measurement.

The self-efficacy questionnaire consists of seven items using a seven-point Likert scale. It was modified from the questionnaire developed by Hwang, Shi, and Chu (2011) for measuring the students' self-efficacy of participating in group learning activities, that is, their expectations and confidence regarding learning in a group. The Cronbach's α value of the questionnaire was 0.82, implying that the questionnaire is reliable.

Experimental results

In the present study, the collected data were first examined by descriptive statistics to explore the group means, standard deviations and numbers. Then, one-directional analysis of variance (ANOVA) was performed on the pre-test scores and the pre-questionnaire ratings of the local culture identity ratings and the self-efficacy of group learning. Analysis of covariance (ANCOVA) was then conducted to examine the effects of using the proposed approach on students' social studies learning achievements, local culture identity and self-efficacy of group learning by analyzing the students' post-test scores and the post-questionnaire ratings.

Learning achievement

Before participating in the learning activity, the students took a pre-test to evaluate their basic knowledge of the science course content. A one-way ANOVA was performed on the pre-test results. The mean values and standard deviations of the pre-test scores were 84.96 and 14.08 for the experimental group, 85.92 and 14.53 for control group A, and 82.46 and 10.81 for control group B. No significant difference was found between the pre-test scores of the three groups with $F = 0.47$ and $p > .05$. Consequently, it is concluded that the three groups had equivalent prior knowledge before the learning activity.

After conducting the learning activity, ANCOVA was performed on the post-test results, in which the pre-test was the covariant, the post-test results were the dependent variable and the "different collaborative learning strategies (three groups)" were the control variable, to compare the post-test results of the three groups. As given in Table 1, the ANCOVA result shows that the difference between the three groups was significant (F (2, 76) = 5.54, $p < .01$) after the impact of the pre-test scores on the post-test was excluded, implying that the post-test scores of the three groups were significantly different due to the different experimental learning processes. Furthermore, *post hoc* analysis was performed to examine specific differences in achievement between the experimental groups, whose adjusted means were 74.51, 60.9 and 65.72, respectively. An least significant difference (LSD) test revealed that the scores of the experimental group (collaborative problem-posing-based mobile learning) were significantly higher than those of control group A (conventional collaborative mobile learning) and control group B (traditional collaborative learning) with $F = 5.54$ and $p < .01$.

Accordingly, it was concluded that the collaborative problem-posing-based mobile learning system was helpful to the students in improving their learning achievements in comparison with both the collaborative mobile learning and the traditional collaborative in-field learning approaches.

Table 1. The ANCOVA result of the learning achievement post-test for the three groups.

Group	*N*	Mean	SD	Adjusted mean	*F* (2,76)	*Post hoc* (LSD)
(1) The experimental group	27	74.89	17.50	74.51	5.54**	(1) > (2)
(2) Control group A	26	62.00	19.75	60.90		(1) > (3)
(3) Control group B	26	64.23	16.56	65.72		

**$p < .01$.

Local culture identity

ANCOVA was used to compare the local culture identity ratings of the three groups after the learning activity by excluding the impact of the pre-questionnaire ratings. According to the non-significant interaction of the independent variable and the covariate of the local culture identity scale (F (2, 76) = 0.44, $p > .05$), the use of ANCOVA is appropriate.

As given in Table 2, the ANCOVA result shows that the local culture identity of the three groups was significantly different (F (2, 76) = 3.32, $p < .05$) after the impact of the local culture identity pre-questionnaire ratings was excluded. Furthermore, *post hoc* analysis was performed to examine specific differences in achievement between the three groups. An LSD test revealed that the experimental group had significantly higher ratings (adjusted mean of 6.30) than control group A (adjusted mean of 5.97) with $F = 3.32$ and $p < .05$. That is, the collaborative mobile learning with the problem-posing approach was able to improve the local culture identity of the students, while the conventional collaborative mobile learning approach did not reveal a promising impact in terms of local culture identity. This finding implies the necessity of providing learning supports during the mobile learning activities, as suggested by researchers.

Analysis of group learning self-efficacy

Table 3 gives the ANCOVA of the post-questionnaire results for the experimental group and control groups A and B. It is found that the post-questionnaire ratings of the three groups were significantly different with F (2, 76) = 5.26 and $p < .01$. Furthermore, *post hoc* analysis was performed to examine specific differences in achievement between the three groups. An LSD test revealed that the experimental group had significantly higher self-efficacy of group learning (adjusted mean of 5.69) than control group A (adjusted mean of 5.07). That is, the collaborative mobile learning system with the problem-posing strategy enhanced the students' confidence in and expectations of learning collaboratively with their peers. On the other hand, for the students in control group A and control group B, there was non-significant difference in this learning activity. A particularly interesting phenomenon is worth noting – that the average self-efficacy rating of the students in control group A (collaborative mobile learning) was lower than that of control group B (traditional collaborative learning), although the difference between the two groups was not significant. A similar situation can also be found in the ANCOVA result of the local culture identity given in Table 2. This finding implies that using new technologies in education does not always lead to better learning performance or perceptions than traditional instruction, depending on how the technologies are used and what has been provided to support the students.

Interview

To further investigate the effectiveness of the problem-posing-based collaborative mobile learning approach, the researchers of this study interviewed eight students in each group

Table 2. The ANCOVA result of the local culture identity post-questionnaire for the three groups.

Group	N	Mean	SD	Adjusted mean	F (2,76)	*Post hoc* (LSD)
(1) The experimental group	27	6.38	0.48	6.30	3.32*	(1) > (2)
(2) Control group A	26	5.90	1.01	5.97		
(3) Control group B	26	6.12	0.63	6.13		

*$p < .05$.

Table 3. The ANCOVA result of the self-efficacy of group learning.

Group	*N*	Mean	SD	Adjusted mean	*F* (2,76)	*Post hoc* (LSD)
(1) The experimental group	27	5.52	1.01	5.69	5.26**	(1) > (2)
(2) Control group A	26	5.24	1.12	5.07		
(3) Control group B	26	5.42	1.08	5.41		

**$p < .01$.

by asking several questions related to the learning approach, such as "What are the major differences between this learning activity and other learning activities in which you have participated?" and "What are the advantages and disadvantages of such a learning activity?"

It was found that all of the students in the experimental group (collaborative problem-posing-based mobile learning) shared a consistent point of view; that is, they considered the benefits of the problem-posing-based collaborative mobile learning approach as "providing systematic guidance," "encouraging in-depth thinking" and "promoting reflection."

In terms of the provision of systematic guidance, seven of the students (87.5%) highlighted the value of the mobile learning system in providing systematic guidance during the learning activity. They believed that this systematic learning approach could increase their learning efficiency owing to the provision of the progressive prompts which helped them raise questions related to the learning targets. For example, one of the students, E01, indicated that, "Unlike the one-to-many training process by teachers, the mobile learning system is much more organized, because it provides step-by-step prompts or hints to help everyone complete the learning tasks." Another student, E05, stated that, "The learners can go over the learning tasks repeatedly with the mobile devices instead of asking the same questions to the teacher or peers."

As for the perspective of encouraging in-depth thinking, six of the students (75%) shared the same position; that is, the process of proposing questions related to the learning targets in the field engaged them in observing, discussing and collecting data in a more thoughtful manner. For example, one of the students, E02, indicated that, "Such a problem-posing task engages me and my group members in thorough discussions and observations." Another student, E06, further stated that, "To complete such a problem-posing task, our group members need to observe and think deeply and thoughtfully. I have never had any similar experience before." Such a finding conforms to what has been reported by Brindley and Scoffield (1998) and Purchase (2000) that problem posing could benefit students in terms of their cognitive growth.

As for the perspective of promoting reflections, all of the students emphasized that the learning approach helped them make reflections during the problem-posing process in the field. Six of the students (75%) expressed the same opinion that they needed to try very hard to recall what they had learned in the class and what they had observed in the field in order to propose questions. Five students (62.5%) further indicated that such a problem-posing-prompt system helped them reflect on what they had learned, no matter whether from the textbook, in-class instruction or the field observations. Such perspectives are consistent with what has been reported by some previous studies, such as Chang (2007) and Chang et al. (2012).

The students in control group A (conventional collaborative mobile learning) mainly focused on the functions provided by the mobile learning system. For example, all of the students stated that the use of the QR code was interesting. Five of the students indicated that the guidance and feedback provided by the system were helpful to them in completing the learning tasks. Five of the students stated the advantage of using the mobile device to read supplemental materials in the field. Two of the students indicated that the screen size of the mobile device was somewhat small; therefore, they suggested using tablets in the future.

On the other hand, the students in control group B (traditional collaborative learning) paid much attention to the teacher's instruction in the field as well as to the learning tasks on the printed learning sheet. Six of the students mentioned that the instructions given by the teacher were clear and helpful. For example, one of the students, CB03, stated that "the introduction given by the teacher is interesting. The stories are helpful to me in remembering the learning targets." Another student, CB06, pointed out that "The instructions given by the teacher are helpful to me in observing the learning targets and completing the learning tasks." Three of the students indicated that the learning missions were somewhat difficult for them. One of the students, CB01, stated that "It is difficult to propose questions. We spent most of the time on answering the questions asked by the teacher, and did not have much time to think of new questions." Another student, CB05, said that "I think the learning tasks are difficult. We need to observe the learning targets, read the printed materials, and discuss with group members to answer the questions. I do not know why we need to propose questions."

Discussion and conclusions

In this study, a two-phase problem-posing strategy is proposed for helping students identify key elements of real-world learning targets and link what they have learned in the field to their prior knowledge learned from textbooks. An experiment has been conducted on an elementary-school local culture course to evaluate the effectiveness of the proposed approach. The experimental results show that the problem-posing-based collaborative mobile learning approach is helpful to the students in improving their learning achievements as well as their local culture identity and group learning self-efficacy. This finding provides evidence to support the expectation of several previous studies that addressed the potential of problem-posing strategies in helping learners comprehend learning content and engage in higher-order thinking (Brindley & Scoffield, 1998; Casagrande et al., 1998; Purchase, 2000). In addition, the finding of this study also reveals the importance of providing effective learning support during the in-field mobile learning activities, as indicated by several previous studies (Chu et al., 2010).

In addition, from the interview results, it was found that the students considered that the problem-posing-based collaborative mobile learning approach was able to provide them with systematic guidance, encourage them to think deeply and engage them in making reflections. Such a finding provides evidence explaining why the post-test scores of the experimental group (collaborative problem-posing-based mobile learning) were significantly better than those of both control groups A and B. It also conforms to what has been reported by previous studies that guiding students to make reflections can benefit them in terms of improving their learning achievements (Hsieh et al., 2011).

From the experimental results, it is also found that the students in control group A (conventional collaborative mobile learning) did not outperform those in control group B (traditional collaborative learning). Such a finding provides a cautionary message that the use of mobile technologies does not guarantee good learning performance; on the contrary, without appropriate learning supports, the performance of mobile learning approaches could be worse than that of traditional instruction. Therefore, although mobile technology can provide individualized or personalized learning facilities in the field, it remains a great challenge to conduct effective mobile technology-supported in-field learning activities.

It is also interesting to find that the “raising questions” strategy did not benefit the students in the traditional collaborative learning approach as much as it did those in the mobile learning approach. This could be attributed to two reasons. First, the problem-posing-based mobile learning system provided a learning guidance mechanism to ensure that individual students identified the key elements related to the learning targets before posing problems. Second, it provided an interactive problem-posing-guiding mechanism with a three-stage progressive prompting approach. During the learning activity, each team of the experimental group students was guided by the learning system to observe the same targets and to pose relevant questions. In the individual problem-posing stages, the students were provided with a prompt of problem-posing from different aspects and were asked to think about and discuss the questions they raised.

On the other hand, each team of students in control group B (traditional instruction with problem-posing) was asked to discuss and write down their questions on a printed learning sheet after the teacher introduced the learning targets. Owing to the teaching reality of traditional instruction, the teacher had difficulty evaluating whether each team of students had correctly identified the key elements of the learning targets before the problem-posing phase. Moreover, the nature of providing hints and supplementary materials on printed sheets caused the students to face a relatively large amount of information at the same time, which might cause overloading of their working memory. As indicated by scholars, providing too much information to students might increase their cognitive load, and hence affect their learning performance (van Merriënboer & Sweller, 2005). Furthermore, the students might selectively read the hints or supplementary materials that provided most information related to their learning tasks, and hence miss the opportunities to think about and pose questions concerning different aspects. Such an explanation complies with the notations indicated by several researchers that providing proper prompts to students is more helpful to them than directly showing solutions, and engaging students in higher-order thinking could benefit them more (Hwang, Wu, & Ke, 2011; Jonassen, Beissner & Yacci, 1993)

Although the local culture course is selected as the main application of this study, it can be seen that such a problem-posing-based mobile learning approach can be generalized to other applications that aim to engage students in higher-order thinking in the field, such as natural science, science and other social science courses. In the future, we plan to investigate the effects of applying the proposed approach to other courses and other grades, such as science courses in elementary schools, mathematics courses in high schools and engineering courses in universities. In the meantime, we will attempt to propose more effective learning supports for in-field mobile learning based on the feedback of the teachers and students who participate in the learning activities. In addition, it is worth investigating how the traditional and mobile approaches can be morphed into a more effective blended learning system.

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