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A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students

Gwo-Jen Hwang [a,*], Hsun-Fang Chang [b]

[a] Graduate Institute of Digital Learning and Education, National Taiwan University of Science and Technology, 43, Sec. 4, Keelung Rd., Taipei 106, Taiwan
[b] Department of Information and Learning Technology, National University of Tainan, 33, Sec. 2, Shulin St., Tainan City 70005, Taiwan

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A B S T R A C T

The advancement of mobile and wireless communication technologies has encouraged an increasing number of studies concerning mobile learning, in which students are able to learn via mobile devices without being limited by space and time; in particular, the students can be situated in a real-world scenario associated with the learning content. Although such an approach seems interesting to the students, researchers have emphasized the need for well-designed learning support in order to improve the students' learning achievements. Therefore, it has become an important issue to develop methodologies or tools to assist the students to learn in a mobile learning environment. Based on this perspective, this study proposes a formative assessment-based approach for improving the learning achievements of students in a mobile learning environment. A mobile learning environment has been developed based on this approach, and an experiment on a local culture course has been conducted in southern Taiwan to evaluate its effectiveness. The experimental results show that the proposed approach not only promotes the students' learning interest and attitude, but also improves their learning achievement.

1. Background and motivation

In the past decade, many studies have demonstrated the benefits of web-based learning. Various learning methodologies or tools have been developed for enhancing the effectiveness of web-based learning, such as the assessment and feedback mechanism (Hwang, Chu, Yin, & Lin, 2008), the learning material recommendation method (Hsu, Hwang, & Chang, 2010), self-explaining prompts (Yeh, Chen, Hung, & Hwang, 2010) and the educational website evaluation criteria (Liu, Liu, & Hwang, 2011). In the meantime, educators have emphasized the importance and necessity of "authentic learning activities" in which students can work with problems from the real world (Brown, Collins, & Duguid, 1989). Therefore, it has become an important and challenging issue to place students in a series of designed lessons that combine both real-world and digital-world learning resources via the use of mobile and wireless communication technologies (Chu, Hwang, Tsai, & Tseng, 2010). In such a new learning environment, students are situated in real-world scenarios with access to the online resources via handheld devices and wireless networks. Such a learning scenario has been called mobile learning (Sharples, Corlett, & Westmancott, 2002) or ubiquitous learning (Hwang, Shih, & Chu, 2010).

There have been various definitions for mobile learning, such as "learning that happens without being limited at a fixed location" and "learning that takes advantage of mobile technologies" (Sharples, 2000). Owing to the popularity of mobile devices (e.g., mobile phones or Personal Digital Assistants, PDAs), most researchers have adopted the latter definition in recent years, as in for example, the studies of Chu, Hwang, Tsai, & Tseng (2010). Several studies have reported the use of mobile technologies in the learning activities of various courses, such as science (Hwang, Wu, Tseng, & Huang, 2010), social science (Chiou, Tseng, Hwang, & Heller, 2010) and language courses (Ogata, Matsuka, El-Bishouty, & Yano, 2009). For example, Chen, Chang and Wang (2008) employed the scaffolding theory to conduct mobile learning activities; in the meantime, Chu, Hwang, Huang, and Wu (2008) conducted several outdoor learning activities in a butterfly ecology garden by integrating mobile learning environments with electronic library facilities. Hwang, Tsai, and Yang (2008) further summarized the characteristics of mobile and ubiquitous learning, and proposed several tutoring and assessment models. Based on those teaching modes,

* Corresponding author. Tel.: +886 915396558.
E-mail addresses: gjhwang.academic@gmail.com (G.-J. Hwang), hsun@dc1es.tnc.edu.tw (H.-F. Chang).

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Hwang, Yang, Tsai, and Yang (2009) employed mobile and wireless communication technologies to develop a learning environment to train students in the equipment operating procedure of the single-crystal X-ray diffraction experiment in a chemistry course; meanwhile, Chu, Hwang, and Tsai (2010) proposed a knowledge engineering approach to develop Mindtools for mobile and ubiquitous learning with sensing technologies (e.g., Radio Frequency Identification, RFID). Shih, Chu, and Hwang (2010) also used these technologies to develop a ubiquitous learning environment for an exploration-based learning activity about campus plants in an elementary school.

In addition to the provision of personal learning supports to the students, researchers have made attempts to develop computer-based support systems for teachers with mobile technologies (Liu et al., 2003). For example, Chen, Hwang, Yang, Chen, and Huang (2009) built a ubiquitous performance support system for teachers (UPSST) to assist them in-class management and in guiding the students' schoolwork. Therefore, mobile and ubiquitous learning has become one of the main issues in this research community.

Compared with traditional instruction or information from textbooks, mobile learning seems to be a more attractive way of learning that can trigger the interest and motivation of the learners. However, most of the previous studies mainly focused on the feedback from students concerning the use of mobile devices in learning, such as the acceptance of the technology (e.g., "ease of use" and usefulness of the mobile learning system) (Chen et al., 2008) and the students' interest in or attitudes toward the mobile learning approach (Chen, Kao, & Sheu, 2003), while the provision of methodologies or tools to improve the students' learning achievements remains an important and challenging issue (Chu, Hwang, & Tsai, 2010; Hwang, Kuo, Yin, & Chuang, 2010a).

To assist the learners in improving their learning achievements in such a situated learning scenario, researchers have given several suggestions for instructional design, including the selection of situations that would afford the particular knowledge to be learned (Chen et al., 2003), the provision of "scaffolding" for learners with different prior knowledge or competence (Williams van Rooij, 2009), the provision of a learning management system for teachers to analyze the learning progress of students (Chen et al., 2009; Peng et al., 2009), and the development of effective mobile learning strategies (Paige & Daley, 2009). Furthermore, researchers have also indicated the difficulty of supporting and guiding learners in such environments that combine real-world and digital-world learning resources (Chu, Hwang, Tsai, & Tseng, 2010). Therefore, it has become an important and challenging issue to develop effective and easy-to-follow learning guidance models for location-aware mobile learning.

To cope with this problem, this study proposes a formative assessment-based approach for mobile learning. Moreover, in addition to learning achievements, students' learning attitudes and cognitive load (including *mental load* and *mental effort* to reflect their intrinsic load which is a combination of extraneous and germane load) (Sweller, Van Merriënboer, & Paas, 1998) are measured to investigate the effects of the proposed approach on the in-field performance of the students from different aspects. The experimental results show that this approach not only promotes the students' learning achievement and attitudes, but also improves their learning achievement with appropriate cognitive load.

2. Learning system with formative assessment-based mobile learning mechanism

In this study, a mobile learning system using the FAML (Formative Assessment-based Mobile Learning) guiding mechanism is developed for conducting a local cultural learning activity with wireless networks and PDAs. This system is implemented with MSSQL, ASP.NET and IIS. Several management functions are developed for teachers, including user profile management, subject materials management, item bank management, and learning portfolio management.

Formative assessment is a process that provides feedback and support during instruction, such that teachers and students can adjust on-going instruction and learning to improve students' achievement of planned instructional outcomes (Black & William, 1998). Nicol and Macfarlane-Dick (2006) further interpreted formative assessment as an integral part of instruction and an important source for students and teachers to make reflections on. It can be the compass to guide students towards learning and academic achievement. Formative assessment has been recognized by educators and researchers as an important element in conducting learning activities for improving student learning effectiveness (Bell & Cowie, 2001). In traditional in-class teaching, it is a form of assessment that is integrated into the interaction between teachers and students for offering feedback to them (Perrenoud, 1998). In the past decade, several studies have reported the effectiveness of applying formative assessment to the learning activities in web-based learning environments. For example, Gardner, Sheridan, and White (2002) developed a web-based learning and assessment system to support flexible education; Orsmond, Merry, and Callaghan (2004) employed a formative assessment model to develop a system incorporating peer and self assessment. Pachler, Daly, Mor, and Mellar (2010) further indicated that almost any technology could be used in a formative way if the right conditions were set in place.

Buchanan (2000) reported that "repeated answering" was an effective format-assessment strategy if it worked under the circumstance that no answer was provided and some references or supplementary materials were given as immediate feedback. Based on the findings of Buchanan (2000), researchers have developed several web-based assessment and test analysis systems, which have shown the positive impact of the three characteristics, "repeated answering", "non-answer provision" and "immediate feedback", on students' learning achievements (Wang, Wang, Wang, Huang, & Chen, 2004). Those characteristics allow the students to repeatedly participate in the "practicing, reflecting and revising" process. That is, the students will *practice* and observe more, gain feedback immediately (*reflect*), and *revise* their answers in response (Wang, 2010).

The aim of proposing the FAML guiding mechanism is to implement those characteristics in a mobile learning environment, in which individual students are situated in a real-world learning environment with personal supports or guidance from the learning system. During the learning process, the mobile learning system guides the students to observe the real-world learning objects and interact with them based on the FAML mechanism. In this study, four or five test items were prepared for each subject unit. After receiving the answers submitted by the students, the learning system provides hints or supplementary materials to the students instead of giving the validity of the answers. Alternatively, they can find the answers via observing the characteristics of the target learning objects in detail. That is, the students need to find out the correctness of their answers on their own.

As shown in Fig. 1, the learning system randomly selects a test item from the item pool of that unit. Once an item has been successively and correctly answered three times, it is removed from the item pool; however, if an incorrect answer is given, the accumulative total of correctness is reset. When the item pool of a unit is empty (i.e., all of the questions in that pool have been

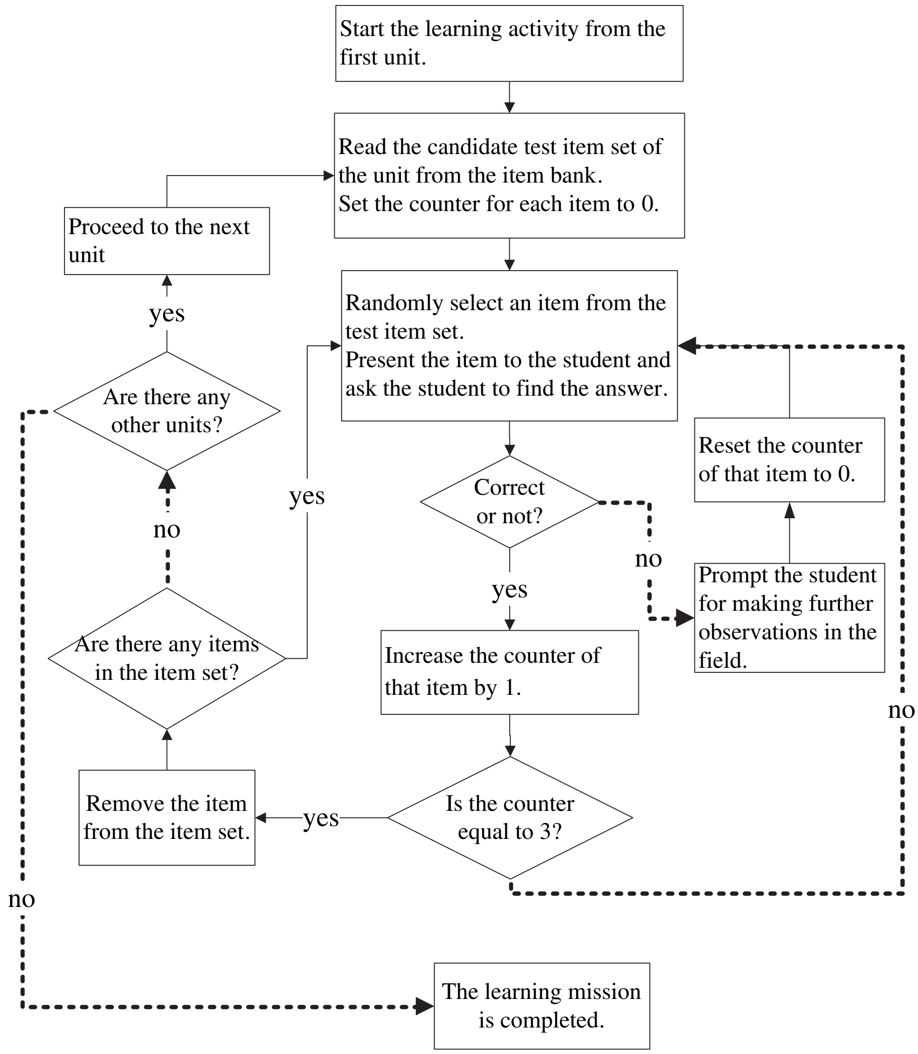

Fig. 1. The formative assessment-based learning guiding mechanism.

successively and correctly answered three times), the students are said to have passed that unit. In this study, each student needs to pass six units of the local culture course.

When the students fail to correctly answer a test item, the learning system does not provide the correct answer to them; instead, it shows some hints to guide the students to make further observations. That is, the students are prompted to find the correct answers on their own. Fig. 2 shows an example of prompting the students who have failed to answer a test item concerning the art forms of an artist in the Qing dynasty to find and observe a wall-painting in the temple. Fig. 3 shows another example of prompting the students to find the answers by reading the text on two kinds of lots of different lengths.

3. Experiment design

To evaluate the effectiveness of this approach, a mobile learning activity was designed for an elementary school's local culture course. The learning environment was Chin-An temple in southern Taiwan, as shown in Fig. 4. The objective of the learning activity was to guide the students to understand the historical background, the transit 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 meanings of and the relationships between those learning targets.

3.1. Learning environment

In the mobile learning environment, a wireless communication network was installed, such that the students were able to interact with the mobile learning system, and access digital learning resources via the mobile devices. The teaching content consisted of five main parts, including the temple square, the front hall, the main hall and the side temples. This learning activity was designed to include six main units, such as the Dutch wells, the stone-carved lions at the main gate and the ridge of the roof, each of which has its own architectural characteristics and historical story.

Fig. 2. Illustrative example of prompting the students to find the answer concerning the art forms of the Qing dynasty.

3.2. Experiment procedure and participants

The participants of this experiment were two classes of fifth grade students of an elementary school in Tainan city. One class (twenty-nine students) was assigned to be the experimental group and the other (thirty-two students) was the control group. Fig. 5 shows the experimental procedures of this study. The students in the control group learned with the conventional tour-based mobile learning approach; that is, the learning system led the students to each target learning object, and guided them to observe the learning object via asking some questions. Once the students submitted their answers, the learning system provided correct answers and relevant supplementary materials to them. On the other hand, the students in the experimental group learned with the Formative Assessment-based Mobile Learning (FAML) approach.

Before and after participating in the experiment, the learning achievements of the two groups of students in the social science course were compared based on their pre-test and post-test scores. Moreover, the learning interest, learning attitude and cognitive load of the two groups of students were analyzed and compared as well.

3.3. Measurement tools

A pre-test and a post-test were developed to evaluate the learning effectiveness of the students. The pre-test (i.e., the most recent mid-term test in the social science course) was composed of 30 multiple-choice items, 10 true-or-false questions and 3 fill-in-the-blank items, giving a full score of 100. The pre-test aimed to detect that the two groups of students had the equivalent basic knowledge and abilities for learning the local culture course. The post-test consisted of 40 multiple-choice items with a full score of 100. Both the pre-test and the post-test were designed by the teacher who taught the local culture course to the two groups of students. The tests were also evaluated by three Social Science educators for expert validity.

Fig. 3. Illustrative example of prompting the students to read the text on the lots of different lengths.

Fig. 4. Scenario of the mobile learning activity for the local culture course.

In addition, a questionnaire with a 4-scale rating scheme was designed to measure the students' interest and attitude levels for taking the local culture course (see the appendix). There were 11 questionnaire items for the "learning interest" aspect and 7 questionnaire items for the "learning attitude" aspect; moreover, the Cronbach's α values for the two aspects were 0.88 and 0.79, respectively, implying that the questionnaire is reliable.

Furthermore, the cognitive load survey proposed by Sweller et al. (1998) was adopted for measuring the cognitive load of individual students. The cognitive load survey consists of four items with a seven-point scale: two items for *mental load* (intrinsic load) and two items for *mental effort* (extraneous and germane load); therefore, the total score for each aspect is 14. *Mental load* is relevant to the number of interacting information elements and the extent to which these elements interact, while *mental effort* is caused when learning activities and/or materials encourage higher-order thinking, and challenge the learner at an appropriate level within what Vygotsky (1978) called their zone of proximal development; that is, mental effort refers to whether the instructional design is poor (extraneous cognitive load) or good (germane cognitive load) enough (Paas & Van Merriënboer, 1994). The Cronbach's α value of the cognitive load form was 0.92. For the *mental effort* and the *mental load* dimensions, the Cronbach's α values were 0.86 and 0.85, respectively. These values show the high reliability of the measurement.

4. Results and analysis

4.1. Learning achievement

Before the experiment, the two groups took a pre-test to ensure that they had equal abilities in this subject before the learning activity. The mean and standard deviation of the pre-test were 83.97 and 12.21 for the experimental group, and 88 and 10.72 for the control group. The *t*-test result showed that these two groups did not differ significantly ($t = 1.37$, $p > .05$); that is, the two groups of students had statistically equivalent abilities before learning the subject unit.

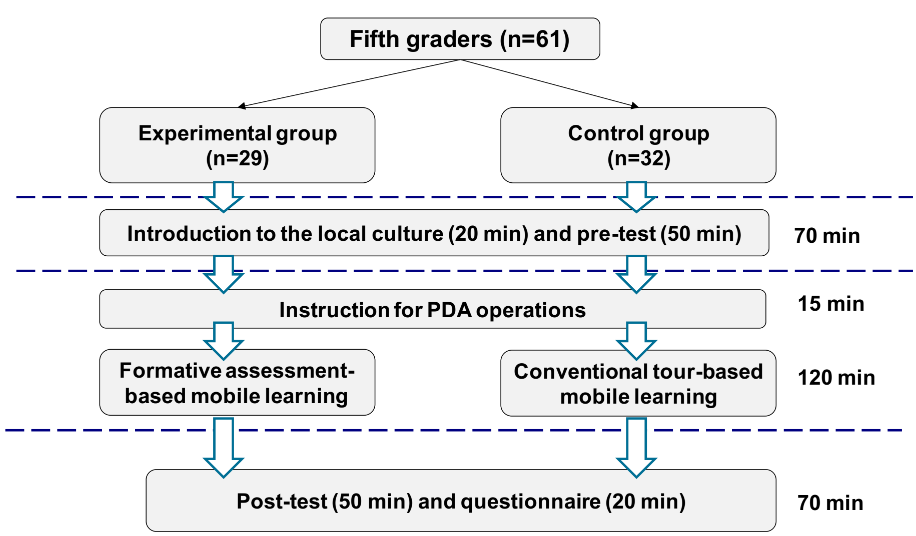

Fig. 5. Experiment procedure.

Table 1
Descriptive data and ANCOVA of the post-test results.

Variable		*N*	Mean	S.D.	Adjusted mean	Std. error.	*F* value	*d*
Post-test	Experimental group	29	63.62	13.72	64.66	2.11	11.54*	0.64
	Control group	32	55.62	11.14	54.68	2.01		

*$p < .01$.

After participating in the learning activity, the two groups of students took a post-test. The ANCOVA result shows that the average learning achievement of the experimental group is significantly better than that of the control group ($F = 11.54$, $p < .01$), as shown in Table 1. The mean score of the experimental group is 63.62, higher than that of the control group, 55.62. In addition, the effect size *d* was computed to measure the strength of the *t*-test result. In Cohen's definition, "$d = 0.2$" indicates "small" effect size; "$d = 0.5$" represents "medium" effect size, and "$d = 0.8$" means "large" effect size (Cohen, 1988). In this study, the *d* value of 0.64 indicates a medium to large effect size, implying that the formative assessment-based approach is helpful to the students in improving their learning achievements in a mobile learning environment.

4.2. Learning interest and learning attitude

Table 2 shows the *t*-test results of the pre- and post-questionnaire scores of the students in the two groups. It is found that after participating in the learning activities, the control group students' learning interest in the local culture course was significantly improved ($t = -2.62$, $p < .05$), while their learning attitude did not show significant improvement.

On the other hand, the pre- and post-questionnaire scores of the students in the experimental group show quite positive results. From the *t*-test results given in Table 2, it can be seen that, after participating in the learning activity, the students had significant improvements in both their "learning interest" ($t = -2.99$, $p < .01$) and their "learning attitude" ($t = -2.39$, $p < .05$). That is, the format-assessment mobile learning approaches improved not only the students' interest, but also their attitudes toward learning the local culture course content. This finding conforms to the previous "learning attitude" studies that have reported the positive effects of students' learning attitudes on their learning achievements (Shaw & Marlowb, 1999; Shih, Chu, Hwang, & Kinshuk, 2010).

4.3. Cognitive load

As the students need to face both the real-world and the digital-world learning resources at the same time, it is quite possible that the burden of individual students exceeds what they can manage; that is, their *cognitive load* could be too high. Cognitive load is concerned with the way in which human's cognitive architecture deals with learning objects during the learning process.

To analyze the reason why learning achievements were not as expected, the cognitive loads of the two groups of students were analyzed and compared. The result is shown in Table 3. It is found that there is no significant difference between the two groups of students in terms of the levels of mental effort ($t = -0.12$; $p > .05$) and mental load ($t = -0.27$; $p > .05$).

This study further compares the cognitive loads of the high, medium and low learning-achievement students in the control group and the experimental group. The *t*-test results in Table 4 show no significant difference between the high and medium learning-achievement students in the two groups. Nevertheless, the low learning-achievement students in the experimental group had significantly higher mental effort than those in the control group ($t = -2.55$, $p < .05$), while the mental load of the two groups of low-achievement students showed no difference.

As mental load refers to the interaction among the task, subject characteristics and learning materials, it represents the "intrinsic cognitive load" which represents the number of different types of information that learners need to integrate in order to understand new information. It is relevant to the inherent structure and complexity of the instructional materials. It increases when the elements' interactivity increases; that is, mental load (or intrinsic cognitive load) is relevant to how much information the working memory needs to deal with at the same time. In this study, the students were arranged to face the same learning materials and learning missions; therefore, it makes sense that the mental loads of the two groups of students did not significantly differ.

On the other hand, mental effort is concerned with the cognitive resources actually allocated to a task, implying that it is affected by the adopted learning approach (Paas, Renkl, & Sweller, 2003; Verhoeven, Schnotz, & Paas, 2009; Zheng, 2009); therefore, it is reasonable that the two low-achievement groups had significantly different levels of mental effort. As the total score of mental effort ranges from 2 to 14, the medium is 8; that is, the mean of mental effort of the students in the experimental group (9.13) was close to the medium score, while that of the students in the control group (5.09) was relatively very low. Researchers have indicated that moderate mental effort (maximizing the effective cognitive load and controlling the ineffective cognitive load) is necessary to students for maintaining good learning performance,

Table 2
The *t*-test result of the pre- and post-questionnaire scores of the two groups.

Group	Dimension		*N*	mean	Standard deviation	T
Control group	Learning interest	Pre-test	32	35.19	5.29	−2.62*
		Post-test	32	38.38	4.41	
	Learning attitude	Pre-test	32	24.41	3.24	−1.44
		Post-test	32	25.50	2.88	
Experimental group	Learning interest	Pre-test	29	35.93	4.76	−2.99**
		Post-test	29	39.24	3.59	
	Learning attitude	Pre-test	29	24.34	3.14	−2.39*
		Post-test	29	26.07	2.28	

*$p < .05$, **$p < .01$.

Table 3
The *t*-test result of the cognitive load levels of the control group and the experimental group.

	Group	*n*	Mean	Standard deviation	*t*	Cronbach's α
Mental load	Control group	32	3.72	2.32	−0.27	0.85
	Experimental group	29	3.90	2.74		
Mental effort	Control group	32	6.09	3.68	−0.12	0.86
	Experimental group	29	6.21	3.53		

Table 4
The *t*-test result of the cognitive load levels of the low-learning achievement students in the control group and the experimental group.

	Low learning-achievement students	*n*	Mean	Standard deviation	*t*	Cronbach's α
Mental load	Control group	11	3.18	1.60	−1.48	0.85
	Experimental group	8	5.50	4.21		
Mental effort	Control group	11	5.09	3.96	−2.55*	0.86
	Experimental group	8	9.13	2.42		

$^{*}p < .05$, $^{**}p < .01$.

and this could be achieved by using effective learning strategies and controlling the instructional variables (Paas & Van Merriënboer, 1994; Paas, Tuovinen, van Merriënboer, & Darabi, 2005). Reinking, Hayes, and McEneaney (1988) also found that reducing extraneous and intrinsic cognitive load might not be sufficient since learners would not automatically use free working-memory capacity to increase effective (or germane) cognitive load. Researchers thus emphasize the importance of guiding learners to engage in cognitively demanding and constructive learning activities to use as much working memory as possible for effective cognitive load (Huk & Ludwigs, 2009). Therefore, it is concluded that the cognitive load of the students who learned with the FAML approach, including those low-achievement students, was appropriate.

5. Conclusions and discussions

The aim of this study is to explore the effect of employing online learning strategies in a mobile learning environment that combines digital learning resources and real-world learning contexts. From the reports of previous studies, the web-based formative assessment has been recognized as being an effective approach that can assist learners in finding out the learning flaws to trigger their motivation for active learning, such that it enables learners to be familiar with the learning content (Wang, 2008, 2010; Wang, Wang, & Huang, 2008). Therefore, it is interesting to examine the effect of applying such an approach to the learning achievements and cognitive loads of students in a mobile learning environment.

In this study, a formative assessment-based learning guiding mechanism is proposed, and a mobile learning environment is developed accordingly. In addition, a mobile learning activity has been conducted to evaluate the effectiveness of our approach by comparing the learning achievements, cognitive load and learning attitudes of the students who learned with or without our approach in such a complex learning scenario. The results show that the formative assessment-based approach is helpful to the students in improving their learning achievements in the mobile learning environment. It should be noted that the students in both the control group and the experimental group spent the same time to complete their learning tasks. The major difference between the two groups was the way they interacted with the mobile learning system. The students in the control group were guided by a tour-based mobile learning system which guided them to visit the same set of target learning objects and asked them the same questions. When the students in the control group failed to correctly answer a question, the learning system showed them the correct answer along with the supplementary materials. Therefore, the students spent most of the learning time on browsing and reading the learning materials. On the contrary, the FAML system only gave hints to the students in the experimental group when they failed to correctly answer a question, implying that they needed to find the answers by themselves. Apparently, the experimental group students spent most of their learning time observing and finding the answers from the target learning objects. From the experimental results, it was found that the students who learned with the FAML approach revealed higher learning motivation and better learning achievement. Consequently, it is concluded that the FAML approach has provided a more challenging learning environment that encourages students to solve the problems on their own in comparison with the conventional mobile learning approach; furthermore, the challenges during the learning process have motivated the students to learn. Moreover, in terms of learning attitude or motivation, the participants in the control group could be discouraged by receiving feedback for "incorrect" responses, while the students in the experimental groups who did not receive any such feedback were less likely to experience a negative reaction and might perceive the experience more favorably. This finding conforms to those of previous studies that have applied the formative assessment strategy to web-based learning (Costa, Mullan, Kothe, & Butow, 2010; Crisp & Ward, 2008; Pachler et al., 2010), even though the new learning scenario that combines both real-world and digital-world resources is much more complex than that of a pure web-based learning environment.

Such a finding reveals the possibility that many computer-assisted learning strategies or tools might have the potential to serve as an effective mobile learning approach for enhancing the learning achievements of the students when they are situated to learn in a real-world environment. For example, it is worth studying the effectiveness or impacts of using several well-known Mindtools, such as concept maps, expert systems, databases and spreadsheets, in mobile learning environments. In addition, we are planning to apply this approach to the learning activities of other courses, including an elementary school natural science course and a university social science course.

On the other hand, there are some limitations in the present approach. First, this intervention was based on a 120 min activity, wherein the mobile learning system was used by participants for the first time. Generalizations about student motivation or attitude would be difficult to make based on such a short timeframe, given that the novelty of the devices had yet to wear off. In the future, the appropriateness of the FAML system, providing vague feedback rather than direct feedback, might be best examined by a mixed design where participants are provided with opportunities to use both types of devices. Testing for higher level thinking skills could be another issue for future research. Moreover, it could be interesting to evaluate learning interest and attitude in terms of the level of achievement if the sample size is large enough.

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Appendix. Questionnaire items for learning interest and attitudes.

Learning interests
1. Local culture courses are interesting.
2. Learning more about local culture is interesting.
3. Visiting ancient buildings (such as temples) is interesting.
4. Visiting people in the community to obtain local cultural knowledge is interesting.
5. Learning with peers in the local culture course is interesting.
6. It is interesting to answer those questions while learning in the field during the local culture course.
7. I always look forward to taking the local culture course and prepare for it before class.
8. The teacher's instructions in the local culture course have attracted my attention.
9. Anything concerning local culture is always interesting to me.
10. The local culture course is more interesting to me in comparison with other courses.
11. Other courses do not attract me as much as the local culture course.

Learning attitudes
1. The local culture course is valuable and worth studying.
2. It is worth learning those things about local culture.
3. It is worth learning the local culture course well.
4. It is important to learn more about local culture, including observing and learning those ancient artworks.
5. It is important to know the ancient history and customs related to our home town.
6. I will actively search for more information and learn about local culture.
7. It is important for everyone to take the local culture course.

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