British Journal of Educational Technology (2015)
doi:10.1111/bjet.12270

Interaction between gaming and multistage guiding strategies on students' field trip mobile learning performance and motivation

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Abstract

In this study, an integrated gaming and multistage guiding approach was proposed for conducting in-field mobile learning activities. A mobile learning system was developed based on the proposed approach. To investigate the interaction between the gaming and guiding strategies on students' learning performance and motivation, a 2×2 experiment was conducted on an elementary school natural science course. Four groups of students were situated in a field trip to learn with different mobile learning approaches (ie, gaming or nongaming) and guiding mechanisms (ie, multistage or single-stage). The experimental results showed that both the gaming and multistage guiding mechanisms proposed in this study significantly enhanced the students' learning achievements. Moreover, the interaction between the two showed that the lead-in of the gaming strategy could significantly improve the learning motivation of the students who learned with the multistage guiding mechanism; on the contrary, their learning motivation could be significantly decreased without the gaming approach, although the multistage guiding mechanism was effective. The findings imply that "gamification" could be a good approach for helping students accept learning support or tools provided in mobile learning scenarios.

Introduction

The rapidly increasing popularity of computer technologies has led researchers to develop technology-based learning strategies and investigate the effects of those strategies on students' learning performance (Ruchter, Klar & Geiger, 2010; Wang & Wu, 2011). Several studies have reported that technology-enhanced learning, if conducted appropriately, could help students to attain better learning performance as well as positive attitudes (Liu, 2009; Looi *et al*, 2011; Pedaste & Sarapuu, 2006). For example, the use mobile devices enables students to learn across contexts and share knowledge with peers without being limited by space or time (Milrad *et al*, 2013). In addition, scholars have emphasized the necessity of situating students in authentic environments where they can experience and meaningfully learn in real-world scenarios (Brown, Collins & Duguid, 1989; Hwang, Yang, Tsai & Yang, 2009). For example, Chu, Hwang and Tsai (2010) have emphasized the necessity of engaging students in solving problems in real-world contexts. Therefore, the use of mobile and wireless communication technologies in educational

Practitioner Notes

What is already known about this topic

- It is important to situate students in authentic environments where they can experience and meaningfully learn in real-world scenarios.
- It is important to develop effective strategies for guiding students to learn in the context-aware mobile learning scenarios that integrate learning resources from the digital world.
- Students might not accept the learning supports or tools that benefit them on the field trip, in particular, problem-based guiding mechanisms.

What this paper adds

- An integrated gaming and multistage guiding approach was proposed for conducting in-field mobile learning activities.
- A mobile learning system was developed based on the proposed approach.
- The study found that the lead-in of the gaming strategy could significantly improve the learning motivation of the students who learned with the multistage guiding mechanism.

Implications for practice and/or policy

- Both the gaming and multistage guiding mechanisms proposed in this study significantly enhanced the students' learning achievements.
- The interaction between the two showed that the lead-in of the gaming strategy could significantly improve the learning motivation of the students who learned with the multistage guiding mechanism.
- The findings imply that "gamification" could be a good approach for helping students accept learning support or tools provided in mobile learning scenarios.

settings has been widely discussed in the past decade (Hwang & Wu, 2014; Sharples, Taylor & Vavoula, 2007). Researchers have called such mobile technology-enhanced learning modes "mobile learning" (Hwang, Shi & Chu, 2011a). Hwang, Tsai and Yang have further used the terms "context-aware mobile learning" and "context-aware ubiquitous learning" to refer to the learning mode that situates students in real-world contexts and tasks with supports from the digital world using mobile devices, wireless communication networks and sensing technologies such as Global Positioning System (GPS), radio frequency identification (RFID) and quick response code (QR code).

In the meantime, researchers have also indicated that, without proper assistance, such mobile technology-supported learning scenarios might be too intricate for the students to learn in an efficient way, and hence, their learning outcomes might not be as good as expected (Chen, Hwang & Tsai, 2014; Hwang, Kuo, Yin & Chuang, 2010). Chu (2014) has also reported that, without a careful learning design, students might feel confused and frustrated when facing both the real-world learning targets and the digital world resources provided via mobile devices. Thus, it is important to develop appropriate learning activities with effective strategies for guiding students in real-world scenarios that integrate the resources from digital world learning environments (Chen & Huang, 2012).

Among various learning support strategies or tools, researchers have stressed the importance of providing learning guidance and feedback as scaffolding to sustain students' learning (Chen, 2010; Huang, Wu & Chen, 2012; Schworm & Gruber, 2012). On the other hand, several studies have reported the challenges of providing learning guidance in mobile learning activities, including the difficulties of designing challenging learning tasks and enjoyable learning contexts (Charsky & Ressler, 2011; Chu, 2014). Therefore, it is important to develop effective learning guiding strategies by taking the acceptance of the students into account.

Researchers have reported the potential of educational computer games for providing enjoyable learning contexts (Charles, Charles, McNeill, Bustard & Black, 2011; Ebner & Holzinger, 2007) and challenging learning missions (Kim, Park & Baek, 2009), and the possibility that they can promote students' learning motivations and performance if the learning materials and tasks can be properly incorporated into the gaming scenarios (O'Neil *et al*, 2014; Wang & Chen, 2010). However, it has also been emphasized that providing effective learning supports in educational computer games remains a great challenge. Without careful design, adding a learning support to a game might have a negative influence on the enjoyment of students while engaged in the gaming process (Barzilai & Blau, 2014).

Thus, in this study, we aim to integrate the "gaming" and "multistage guiding" strategies into the context-aware mobile learning environment. The former is the approach that situates students in challenging and enjoyable tasks, while the latter is the approach which provides effective learning guidance and feedback. A 2×2 experiment was conducted to investigate the effects of the "gaming" and "multistage guiding" approaches, and their interaction, on students' learning achievements and motivation.

Literature review

Mobile technology-enhanced learning

In recent years, owing to the rapid evolution and prevalence of mobile devices, researchers have taken advantage of them to provide learning materials which can be accessed at any time and from anywhere (Looi *et al*, 2011). Furthermore, the advances in wireless and communication technologies have enabled researchers to foster educational strategies for providing learning supports (Wang & Wu, 2011). These developments have facilitated various new learning approaches which enable outdoor learning without the limits of time and place. Such technology-enhanced learning could afford students the opportunities to attain better learning effectiveness (Liu, 2009). For example, some studies have demonstrated the benefits of mobile technology-enhanced learning, such as the provision of individual inquiry learning experience, in-field activities and timely learning assistance (Hwang *et al*, 2011a; Ruchter *et al*, 2010).

Moreover, previous studies have illustrated the significance of situating students in authentic environments where they can meaningfully learn in the real-world scenarios (Brown *et al*, 1989; Hwang *et al*, 2009). Such learning scenarios have been named mobile learning or ubiquitous learning (Hwang, Tsai & Yang, 2008; Shin, Kuo & Liu, 2012). Previous research has demonstrated the effectiveness of mobile technologies in various learning domains, such as foreign language (Liu, 2009) and natural science (Looi *et al*, 2011). For example, Ruchter *et al* (2010) utilized a mobile guidance system for environmental education activities and found that the computer as mobile guide can increase the students' environmental knowledge as well as their motivation.

Furthermore, the rapid advances in sensing technology have facilitated many ubiquitous computing applications (Liu, Tan & Chu, 2009) such as QR-code, RFID, GPS and Augmented Reality. Such advancements can further afford good opportunities for designing technology-enhanced learning systems to guide learners in context-aware learning environments (Chen, Chang & Wang, 2008). For example, Chen and Huang (2012) employed context-awareness techniques to situate students in a u-museum and confirmed that most students' learning achievement improved significantly.

Previous empirical experiments have also evidenced the difficulties of conducting learning activities to guide students to learn the appropriate thing in the right place at the right time. This is because such learning scenarios might be too intricate for the students to learn without appropriate assistance. Thus, it is important to develop proper activities or strategies for guiding students in real-world scenarios that integrate the resources from digital world learning environments (Chen & Huang, 2012) in order to facilitate their learning.

Guiding and feedback strategies

Prompts could assist students in identifying concepts and help them organize their knowledge. Consequently, learning guiding strategies, such as the provision of prompts and feedback, have been regarded as an adequate instructional approach for providing learning supports (Manlove, Lazonder & de Jong, 2007; Schworm & Gruber, 2012). In previous studies, researchers have designed diverse mechanisms for providing learning guidance for different learning activities. Recent research has also demonstrated that providing proper learning guidance during the learning process has great benefits for students' learning effectiveness (Wilson, Perry, Anderson & Grosshandler, 2011). For example, Schworm and Gruber (2012) employed instructional prompts to enhance students' learning outcomes and more active participation in online learning activities.

Prompts, a kind of learning guidance, can trigger meaningful learning and facilitate students' reflection on what they have learned (Chen, Wei, Wu & Uden, 2009; Pressley *et al*, 1992). Several studies have proved the benefits of providing learning support in helping learners achieve a desired skill or knowledge level (Chen, Kao & Sheu, 2003; Sharma & Hannafin, 2007), and engage in reflection (Chen *et al*, 2009; Hwang, Wu & Ke, 2011b; Pressley *et al*, 1992). On the other hand, the learning effectiveness of the students could fail without proper supportive tools, strategies or prompts, especially in in-field mobile learning environments (Huang, Wu & Chen, 2012; Hwang *et al*, 2011a), implying the indispensability of affording proper learning support to assist students in enhancing the connections between what they have observed and learned in the field. For example, Sung, Hwang, Liu and Chiu (2014) employed a question-based annotation approach to develop mobile learning systems for guiding students to learn in an architecture design course, and found that this proposed approach promoted the students' self-efficacy as well as their learning achievements.

Research has also identified the challenges of providing guidance during the learning activity (Fiorella, Vogel-Walcutt & Fiore, 2012). Students might ignore or neglect the guidance (eg, prompts) if they receive no feedback or guidance regarding their responses or if they could not comprehend the relationship between the guiding information and the problems (Furberg, 2009; Hsu & Tsai, 2013). Thus, it would be significant to have better guiding strategies to help them comprehend what the guiding information represents or reflects during the learning activities.

Various kinds of learning guiding strategies have been proposed to assist the learning activities in mobile learning environments, such as text-based prompts or multimedia prompts. For example, Hung, Yang, Fang, Hwang and Chen (2014) declared that the reflection levels and learning attitudes of students were significantly improved by utilizing video-based prompts in the context-aware ubiquitous learning environment. Furthermore, some research has confirmed that providing prompts in a progressive way could enhance learners' recognition of the learning concepts (Tsai & Chou, 2002). For example, Chen, Hwang and Tsai (2014) employed a progressive prompting approach to conduct learning activities in a context-aware learning environment for natural science courses and to promote students' learning achievements. However, in terms of learning motivation, there was no difference between the students with the progressive prompting approach and those with the conventional approach during the context-aware learning activities. Thus, the purpose of this study was to develop a new learning approach to further promote the students' learning achievements as well as their learning motivation.

Digital game-based learning

Digital game-based learning (DGBL) provides a context which involves a set of game goals, educational objectives and rules designed to enhance students' learning effectiveness (Erhel & Jamet, 2013; Huang, Huang & Tschopp, 2010). Thus, it has been an irresistible trend to employ educational games in learning environments (Moreno-Ger, Burgos, Martínez-Ortiz, Sierra & Fernández-Manjón, 2008). In recent years, several studies have demonstrated the benefits of computer games for education, such as mathematics (Bai, Pan, Hirumi & Kebritchi, 2012), brain training (Miller & Robertson, 2010), natural science (Meluso, Zheng, Spires & Lester, 2012; Sung & Hwang, 2013) and foreign language (Liu & Chu, 2010). Many previous studies have also illustrated the benefits of utilizing educational computer games in helping students enhance their learning performance (Sampayo-Vargas, Cope, He & Byrne, 2013), as well as their learning motivation (Ronimus, Kujala, Tolvanen & Lyytinen, 2014; Vos, van der Meijden & Denessen, 2011; Wang & Chen, 2010). For instance, Erhel and Jamet (2013) investigated the effects of DGBL and found that such an approach can promote students' learning and motivation.

Although some researchers have revealed the benefits of DGBL, others have asserted the opposite view. The negative results of DGBL normally associated with learning activities are due to the lack of transferring motivational engagement from gaming to educational situations (Hoffman & Nadelson, 2010). Similarly, digital games are still resources which are difficult to utilize in education (Sancho, Moreno-Ger, Fuentes-Fernandez & Fernandez-Manjon, 2009), due to the differences in the educational and gaming contexts. Therefore, the empirical effectiveness of DGBL remains a challenging issue (Tsai, Yu & Hsiao, 2012), and it is certainly essential to realize how to take advantage of it.

An educational game, which contains some playable elements, can engage students in challenging learning activities. For instance, some structural elements of the games proposed by Prensky (2007), such as rules, goals, objectives, outcome, feedback, conflict, competition, challenge, opposition, interaction, representation or story may increase the playability of the games. In principle, gaming is not only socially fascinating, fun and challenging but also relaxing for players (Hoffman & Nadelson, 2010). Furthermore, Moreno-Ger *et al* (2008) asserted that an educational game design needs to involve the requirements of "integration with online education," "adaptation" and "assessment." In general, challenge and social interaction are indispensable to an educational game.

In recent years, on account of the popularity of mobile devices, researchers have developed mobile games (Laine, Sedano, Joy & Sutinen, 2010; Wong, Hsu, Sun & Boticki, 2013) or ubiquitous games that situate students to learn in real-world environments (Liu & Chu, 2010). For example, Sánchez and Olivares (2011) conducted learning activities based on Mobile Serious Games to develop the skills of collaborative problem solving. Ubiquitous environments afford opportunities to develop learning activities for engaging students in situations that integrate digital with real-world resources. However, one of the challenges of game-based learning is to assist students in making connections between what they have learned in the game and what they have learned at school by maintaining a high level of engagement in the gameplay (Barzilai & Blau, 2014). This also reveals the significance of the appropriate game design.

As just mentioned, learning guidance or scaffolding can trigger meaningful learning and facilitate students' reflection on what they have learned (Chen *et al*, 2009; Pressley *et al*, 1992). Nevertheless, providing scaffolding for a game might have a negative influence on the students' perceptions of learning and enjoyment of the game (Barzilai & Blau, 2014). It may not be easy for

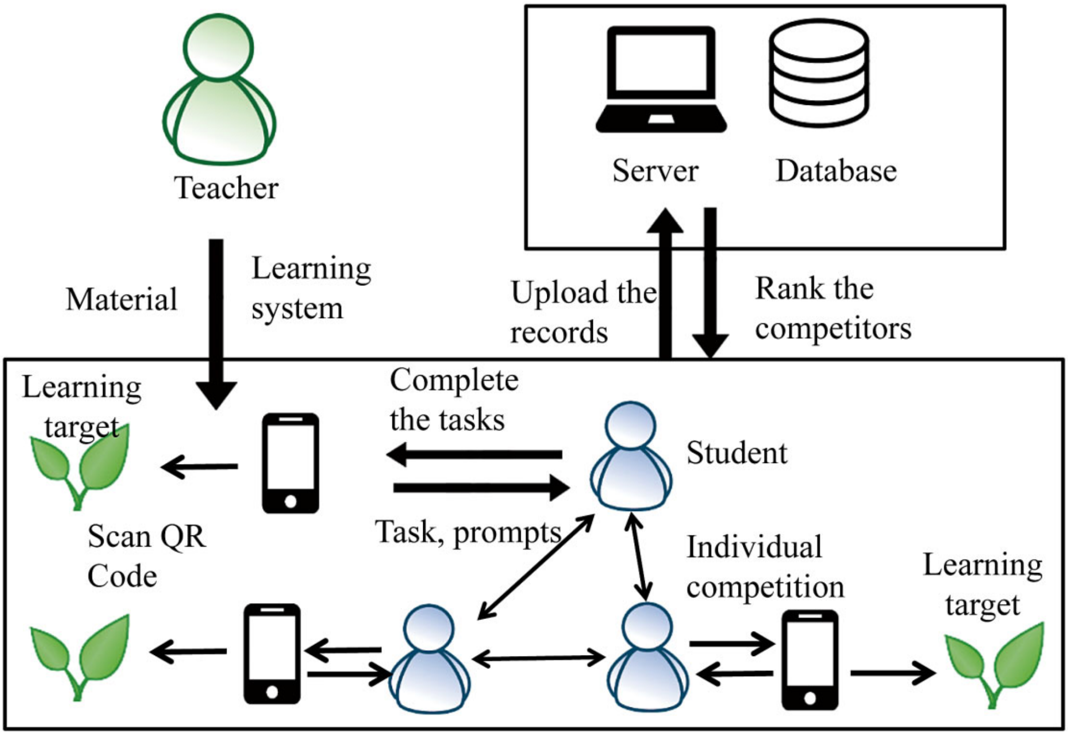

Figure 1: Structure of the mobile learning system with the integrated gaming and multistage guiding mechanisms for conducting in-field learning activities

students to maintain the pleasurable experience during the learning process. Thus, it is crucial to design a proper learning guiding approach by leading in some strategies (eg, gaming) that might engage the students in the learning tasks in an enjoyable manner.

Context-aware mobile learning system with an integrated gaming and guiding approach

In this study, an integrated gaming and multistage guiding approach was developed to support in-field learning activities. Based on this approach, a context-aware mobile learning system was developed using JAVA Eclipse, and QR Codes were adopted to ensure that the learners found the right learning targets in the field (eg, plants on the school campus). In addition, every student was equipped with a tablet computer for interacting with the learning system and environment during the learning activities. The structure of the mobile learning system is shown in Figure 1.

Figure 2 shows the gaming interface, which is a map representing the real-world learning environment. On the map, there are several tagged locations, which represent the targets to be observed on the field trip. At the beginning of the game, individual students are randomly assigned a location on the gaming map with an initial gaming score. They need to throw a dice to determine their move (ie, 1–6). When the gamers move to a location on the map, they are asked to observe the corresponding learning target in the real-world. According to the individual gamers' locations, the learning system presents a gaming task of a multiple-choice question or a matching game to guide them to learn. At most locations, a multiple-choice question is presented, while in some particular locations, the gamers need to complete a matching game.

Figure 3 shows the snapshot of a multiple-choice question when gamers arrive at a location with a learning target (ie, a plant). First, they are asked to scan the QR Code on the target to confirm

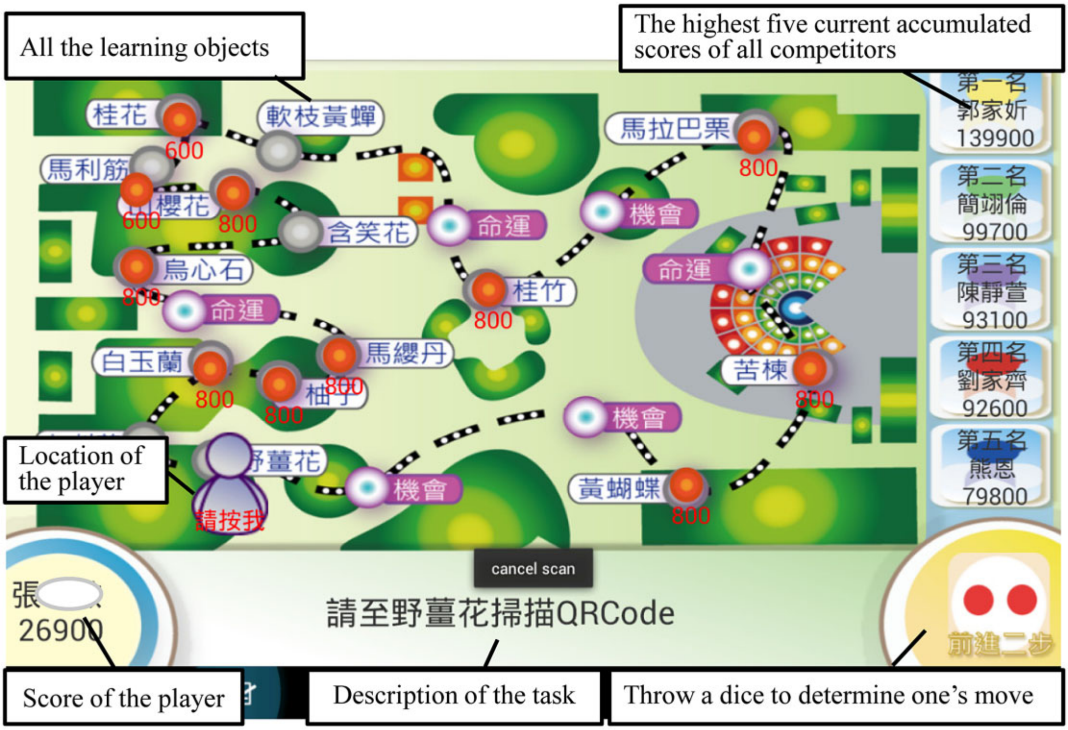

Figure 2: Interface of the in-field gaming system

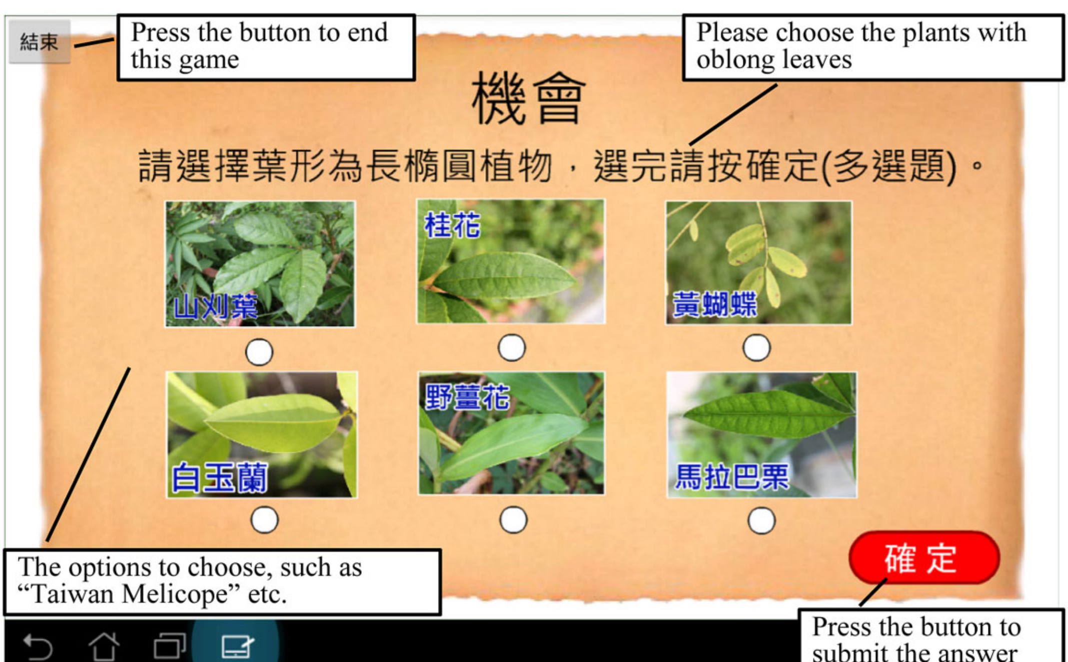

Figure 3: Snapshot of a multiple-choice question associated with a real-world location

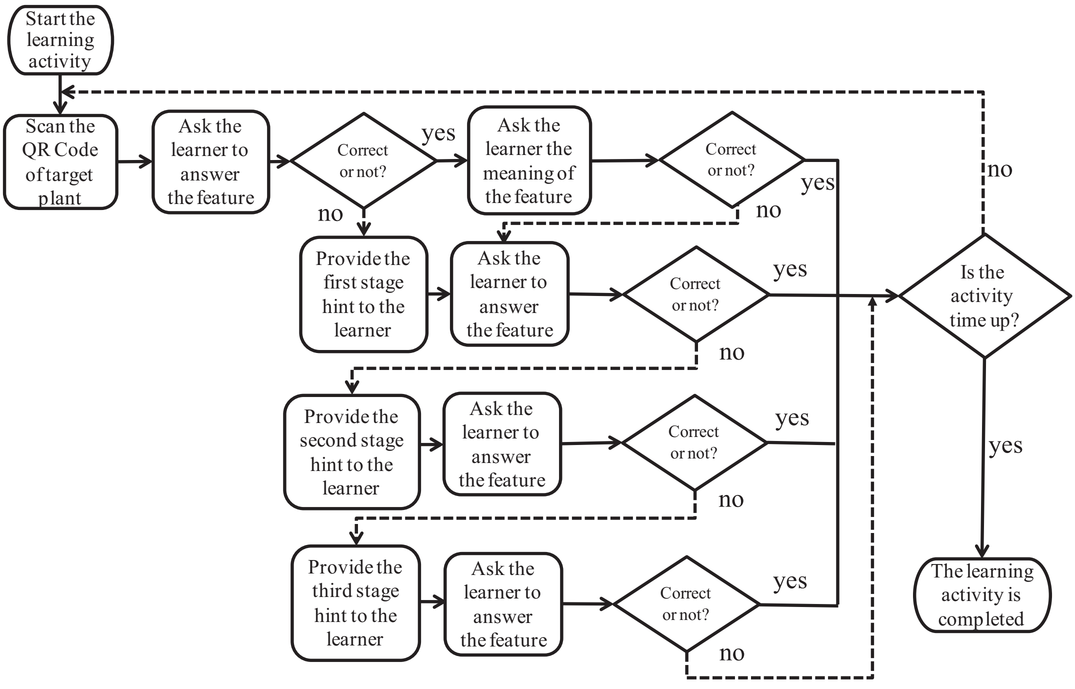

Figure 4: The multistage guiding mechanism for developing the mobile game for in-field learning

their real-world location. Following that, they need to answer questions about the features of the target plant by means of making observations of the target.

When the students correctly reply to a question or finish a matching game, the learning system increases their individual score. Moreover, the learning system shows the highest five current scores of all students on the board; hence, they know who the top competitors are. After correctly completing a gaming task, the students need to throw the dice again and move forward. If they move to the location of the same plant two or more times, the learning system displays questions regarding different features of the plant. All students constantly execute the gaming task till the time is up.

On the other hand, if the students fail to correctly answer a question, the learning system assists them in recognizing the right characteristics by employing a multistage guiding mechanism, as shown in Figure 4.

When students fail to correctly answer a multiple-choice question for the first time, the learning system provides a first-stage hint, which guides them to compare the features of the learning target with those of a comparative target which has the incorrect feature chosen by the students. For example, as soon as an incorrect answer "sword-shaped" is chosen for depicting "Pachira aquatica" in the first stage, the learning system then guides the student to find the comparative target "furcraea foetida" which is "sword-shaped," and to compare the leaf shapes of the two plants, as shown in Figure 5.

If the students fail to correctly identify the same feature of a learning target again, the learning system provides them with a sketch map and text descriptions of the learning targets in the second stage (see Figure 6a); moreover, if the learners could still not correctly recognize the

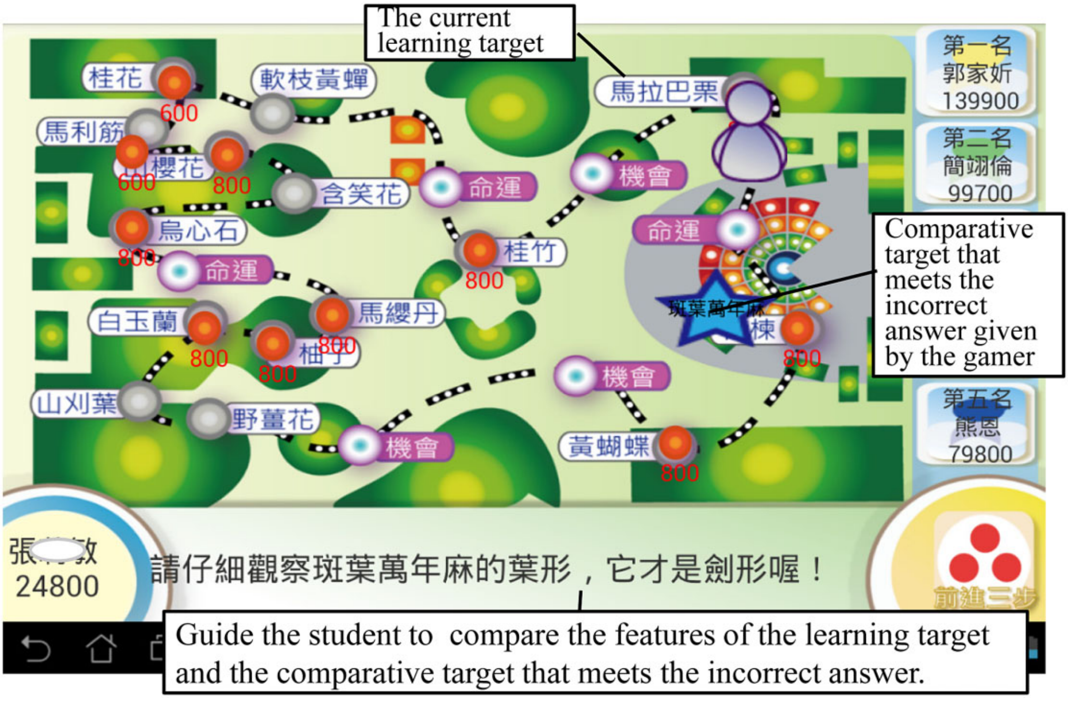

Figure 5: Example of the first-stage prompts provided to the learners during the gaming process

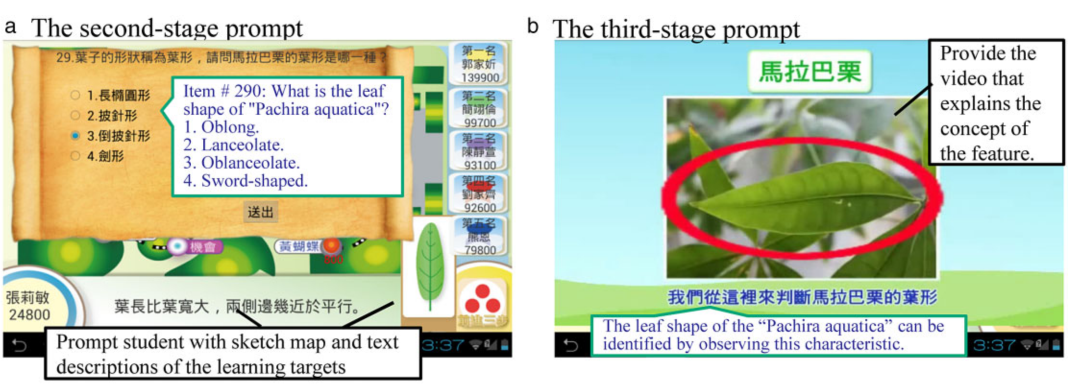

Figure 6: Example of the (a) second- and the (b) third-stage prompts

feature the third time, the learning system then provides them with a video that explains the concept of the feature (see Figure 6b). The more time the students spend on answering a question, the lower their gaming score.

In order to increase the entertainment of the activity, in the real-world gaming approach, if the students correctly recognized the feature of a learning target on their first attempt and precisely chose the meaning of the feature, they could decide whether to "purchase" the property or not. A total of 15 plants were provided in this experiment. The students could promote the value of their property (ie, raise the value of the plants they own) when re-visiting the plants by successfully recognizing more features of the plants. On the other hand, when the students moved to a

Table 1: The different treatments for the four groups in this experiment

	Multistage guiding	*Single-stage guiding*
Game	G-M group (experimental group 1): gaming and multistage guiding	G-S group (experimental group 2): gaming and single-stage guiding
Nongame	N-M group (experimental group 3): nongaming and multistage guiding	N-S group (control group): nongaming and single-stage guiding

location owned by other students, part of their gaming scores were transferred to the owner, depending on the value of the corresponding property (ie, the growth of the plant) on that location.

Research questions

In this study, a multistage guiding-based gaming approach is proposed to program a context-aware ubiquitous learning system for supporting students to learn while taking part in authentic activities. An experiment has been conducted on a natural science course of an elementary school to explore the effectiveness of the proposed approach via investigating the following research questions:

(1) What are the impacts of the gaming and guiding approaches, and the interaction between them, on the students' learning achievements in the context-aware learning activities?
(2) What are the impacts of the gaming and guiding approaches, and the interaction between them, on the students' learning motivation in the context-aware learning activities?

Methods

Participants

The participants of this experiment included four classes of fifth graders (10- and 11-year-olds) who studied natural science for four periods a week in an elementary school in northern Taiwan. A total of 97 students (46 females and 51 males) participated in this experiment. One class was assigned to be experimental group 1 ($n = 27$), one class was experimental group 2 ($n = 25$), one class was experimental group 3 ($n = 24$) and another class was the control group ($n = 21$). The treatment of the different groups in this experiment is shown as Table 1. All groups were taught by the same teacher in their regular science course, a female teacher with more than 10 years of elementary school science teaching experience.

Experimental procedure

The in-field mobile learning activities were conducted for the "recognizing the plants on the school campus" unit of the natural science course to evaluate the effectiveness of the integrated gaming and multistage guiding approach by examining the learning achievements and motivation of the students who learned with different approaches in the field.

Figure 6 shows the real-world learning environment, which consisted of 15 kinds of plants for the students to recognize and compare, such as "Magnolia denudate" and "Hedychium coronarium." Each student was provided with a tablet computer to learn in an authentic learning environment. Moreover, QR Codes were used to identify the locations of individual learners and facilitate the learning system to provide suitable learning affordances at the right time and in the right place. The experimental procedure consisted of four learning approaches as shown in Figure 7.

Figure 8 shows the experimental procedure. Before the experiment, the students completed a five-period unit (200 minutes) to learn the fundamental knowledge of plants, a part of their usual natural science course. Afterwards, the students took the pretest and completed the prequestionnaire of learning motivation.

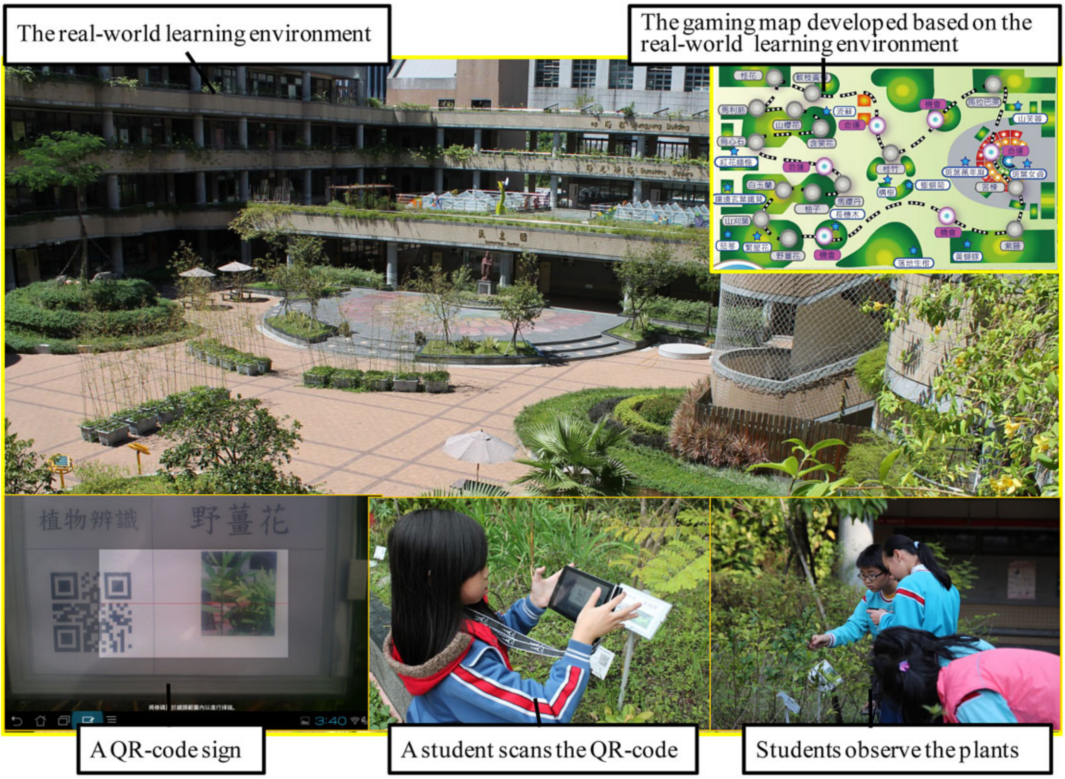

Figure 7: An example of the learning activity

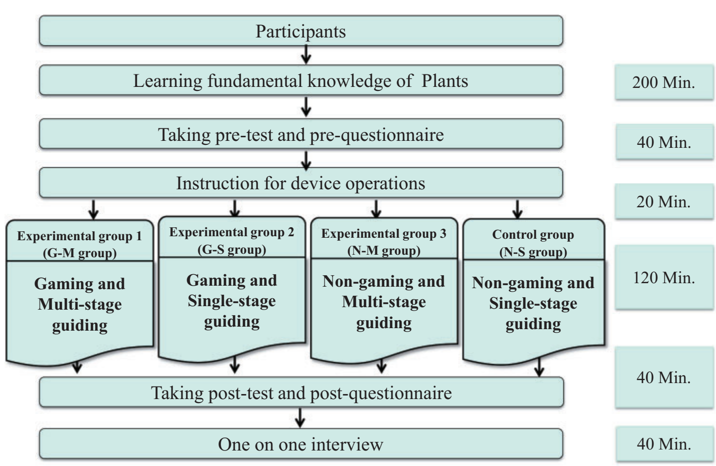

Figure 8: The experiment procedure

Before the learning activity, the students were instructed to appropriately operate the tablet computer and learning system. During the learning activity, the students in all groups learned with different mobile learning approaches to interact with the real world and perform the learning tasks for 120 minutes. The learning material and the content of the guidance provided for the four groups were all identical. The differences between the four groups were the way of

Table 2: The descriptive data of the learning achievements for the four groups

		Pretest		*Posttest*		
Gaming mechanism	*Guiding mechanism*	M	SD	*Adjusted* M	SD	n
Game	Multistage guiding	*62.78*	*12.73*	75.48	2.48	27
	Single-stage guiding	*69.20*	*15.18*	67.31	2.59	25
	Total	*65.87*	*14.20*	71.38	1.78	52
Nongame	Multistage guiding	*62.08*	*13.43*	66.84	2.64	24
	Single-stage guiding	*68.60*	*14.62*	54.67	2.81	21
	Total	*64.89*	*14.16*	60.76	1.92	45
Total	Multistage guiding	*62.45*	*12.94*	71.14	1.82	51
	Single-stage guiding	*68.70*	*14.77*	60.99	1.92	46
	Total	*65.41*	*14.12*	66.07	1.31	97

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

presentation, that is, via the gaming (G) or nongaming (N) interface with multistage (M) or single-stage (S) guidance. When an incorrect answer was chosen, the learning system activated the guiding mechanism. At this moment, the multistage guiding approach provided the students with content in three stages, as previously described, whereas the single-stage approach provided them with the full guiding content all at once.

After completing the learning activity, the students were asked to take the posttest and fill out the post-questionnaire of learning motivation to measure their learning effectiveness. Finally, six students from each group were interviewed by the researchers to collect their opinions on the learning activity.

Measuring tools

In this study, the measuring tools included the pretest, the posttest and the questionnaire of learning motivation for measuring the students' perceptions of the learning activity.

The purpose of the pretest was to evaluate whether the four groups of students had an equivalent basic knowledge of plants before attending the learning activity. It had a perfect score of 100 and consisted of 20 multiple-choice items. The posttest aimed to assess the students' knowledge of recognizing features of the plants. It consisted of 20 multiple-choice items (30%) and eight matching questions (20%). Both the pretest and posttest were developed by two elementary school teachers with more than 10 years of elementary school science teaching experience.

The questionnaire of learning motivation was modified based on the questionnaire developed by Hwang, Yang and Wang (2013). It consisted of seven items using a 5-point Likert rating scheme, such as "I will actively search for more information and learn about recognizing the plant unit" and "I would like to learn more and observe more in the recognizing the plant unit." The Cronbach's α value of the questionnaire administered in the original study was .79, showing acceptable reliability in internal consistency.

Experimental results

Learning achievement

To explore the learning achievements of the four groups, a two-way ANCOVA was employed using the pretest scores as the covariate, the gaming mechanism (divided into the gaming and nongaming approaches) and the guiding mechanism (divided into the multistage guiding and the single-stage guiding approaches) as independent variables, and the posttest scores as the dependent variable. The descriptive data of the learning achievement for all four groups are shown in Table 2.

Table 3: Results of two-way ANCOVA on students' learning achievements

Source	SS	df	MS	F	η^2
Pretest (covariate)	*2257.99*	*1*	*2257.99*	*13.75****	*0.130*
Guiding	2359.25	1	2359.25	14.37***	0.135
Gaming	2709.15	1	2709.15	16.50***	0.152
Guiding* gaming	97.37	1	97.37	0.59	0.006
Error	15 106.80	92	164.20		

*Interaction between guiding and gaming approaches; ***$p < .001$.

Table 4: Results of two-way ANCOVA on students' learning motivation

Source	SS	df	MS	F	η^2
Guiding	0.08	1	0.08	0.20	0.002
Gaming	1.04	1	1.04	2.49	0.026
Guiding* gaming	2.84	1	2.84	6.84*	0.069
Error	38.25	92	0.42		

*Interaction between guiding and gaming approaches; *$p < .05$.

After verifying that the assumption of homogeneity of regression was not violated ($F = 0.38$, $p > .05$), the ANCOVA result is shown in Table 3. It is found that the effect on the interaction between the gaming mechanism and the guiding mechanism was not significant ($F = 0.59$, $p > .05$). Thus, it is sensible to directly examine the main effects of the independent variables. It was found that significant effects were confirmed for the gaming mechanism ($F = 16.50$, $p < .001$, $\eta^2 = 0.152$), and for the guiding mechanism ($F = 14.37$, $p < .001$, $\eta^2 = 0.135$) on the students' learning achievements. This implies that the posttest ratings of the students were significantly different due to the different learning approaches (ie, gaming or nongaming) as well as the different guiding approaches. Thus, it was concluded that the students who utilized the mobile learning system with the multistage guiding mechanism (the G-M and N-M groups; adjusted mean = 71.14, $SD = 14.16$) outperformed those who used that with the single-stage guiding mechanism (the G-S and N-S groups; adjusted mean = 60.99, $SD = 15.11$) in terms of improving their learning achievements. On the other hand, the students who employed the mobile game (the G-M and G-S groups; adjusted mean = 71.38, $SD = 14.56$) outperformed those who studied with the conventional mobile learning system in terms of improving their learning achievements (the N-M and N-S groups; adjusted mean = 60.76, $SD = 13.60$). Moreover, based on the definition indicated by Cohen (1988), the effect size (η^2) of the ANCOVA results of the guiding mechanism and the gaming mechanism represents a moderate effect size ($\eta^2 = 0.135 > 0.059$) and a large effect size ($\eta^2 = 0.152 > 0.138$) respectively.

Learning motivation

In this study, a two-way ANCOVA was employed to investigate the learning motivation of all four groups. The pretest scores of motivation were used as the covariate, the gaming mechanism and guiding mechanism were the independent variables, and the posttest scores of motivation were a dependent variable.

The assumption of homogeneity of regression was examined for all four groups' ratings of learning motivation, and for confirming that the assumption was not violated with $F = 1.30$ ($p > .05$). As shown in Table 4, the ANCOVA result indicated that a significant effect was proved for the interaction between the independent variables ($F = 6.84$, $p < .05$, $\eta^2 = 0.069$) on the

Table 5: The descriptive data of the learning motivation divided by gaming mechanism

Gaming mechanism	*Guiding mechanism*	*Adjusted mean*	*Standard error*
Game	Multistage guiding	4.63	0.13
	Single-stage guiding	4.33	0.13
Nongame	Multistage guiding	4.08	0.13
	Single-stage guiding	4.49	0.14

Table 6: Results of the simple main effect analysis of students' learning motivation

Variables	SS	Df	MS	F	η^2
Guiding mechanism					
Game	1.13	1	1.13	2.71	0.051
Nongame	1.18	1	1.81	4.31*	0.095
Gaming mechanism					
Multistage guiding	3.53	1	3.53	8.48**	0.213
Single-stage guiding	0.29	1	0.29	0.70	0.012

*$p < .05$; **$p < .01$.

students' learning motivation. Thus, it was necessary to employ a simple main effect analysis to investigate the effects of the prompt approaches on the learning motivations of the students who participated in the learning activities with different game approaches.

The descriptive data on the adjusted posttest scores of motivation of all four groups are shown in Table 5, while the results of the simple main effect analysis are shown in Table 6. In terms of the gaming mechanism, it is found that the students who learned with different guiding approaches showed significantly different learning motivations ($F = 4.31$, $p < .05$, $\eta^2 = 0.095$); that is, the learning motivation of the nongame and single-stage guiding group (the N-S group; adjusted mean = 4.49; $SD = 0.65$) was significantly higher than that of the nongame and multistage guiding group (the N-M group; adjusted mean = 4.08; $SD = 0.67$). On the other hand, no significant difference was found between the learning motivations of the students who learned with the mobile game with different guiding approaches.

With regard to the impact of the guiding mechanism, a significant difference ($F = 8.476$, $p < .01$, $\eta^2 = 0.213$) was verified between the students who learned with the gaming and nongaming approaches with the multistage guiding mechanism, whereas no significant difference was found between those who learned with the gaming and nongaming approaches with the single-stage guiding mechanism. This implies that the learning motivation of the gaming and multistage guiding group (the G-M group; adjusted mean = 4.63; $SD = 0.47$) was significantly higher than that of the nongaming and multistage guiding group (the N-M group; adjusted mean = 4.33; $SD = 0.81$). That is, using the gaming approach can promote the motivation of the students who participated in the mobile learning activity with the multistage guiding mechanism.

Figure 9 shows the interaction between the gaming mechanism and guiding mechanism of the students' learning motivation. It shows that, in the mobile learning activity without the gaming mechanism, the learning motivation of the students who learned with the multistage guiding approach was significantly lower than that of the students who learned with the single-stage guiding approach. On the other hand, in the learning activity with the multistage guiding mechanism, the learning motivation of the students who learned with the gaming approach was

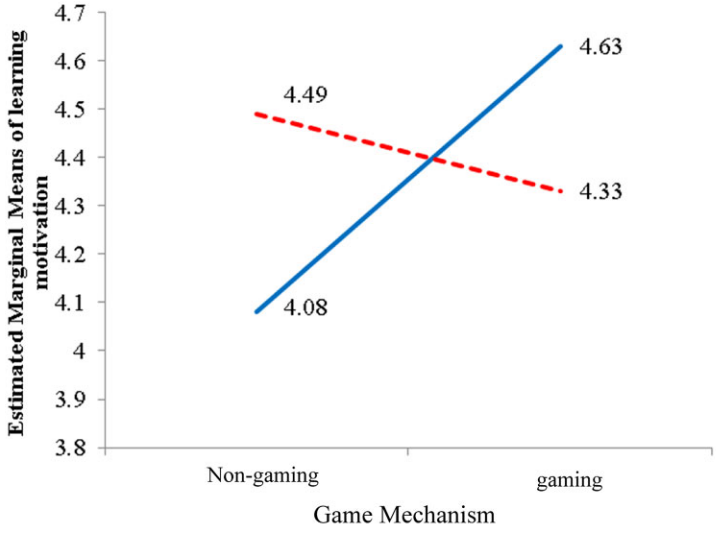

Figure 9: Interaction between the gaming mechanism and guiding mechanism on learning motivation. —, multi-stage guiding; ----, single-stage guiding

significantly higher than that of the students who learned without the gaming approach. This indicates that the gaming mechanism was very helpful to the students who learned with the multistage guiding approach in terms of enhancing their learning motivation.

Discussion and conclusions

In this study, an integrated gaming and multistage guiding approach was employed in the development of a context-aware mobile learning system for guiding students to learn in the field. Moreover, an experiment was conducted on an elementary school natural science course to explore the effectiveness of the proposed approach. The experimental results showed that the proposed approach significantly improved the students' learning achievements and learning motivation.

Although the interaction between the gaming and guiding mechanisms on the students' learning achievement was not significant, each of the two mechanisms showed a significantly positive effect on the students' learning achievements. This result corresponds to the opinion of several researchers, namely that the provision of proper learning supports (eg, multistage guiding) is indispensable for improving students' learning outcomes in mobile technology-enhanced in-field learning activities (Chen & Huang, 2012; Chu *et al*, 2010). This is also consistent with the findings of several previous studies, revealing that providing adequate supports during in-field mobile learning processes can improve students' learning achievements (Hwang *et al*, 2011a; Wang & Wu, 2011). In the meantime, the effectiveness of the gaming mechanism also corresponds to some previous studies that have asserted the benefits of applying educational computer games to help students enhance their learning performance; that is, gaming has great potential for motivating students via providing challenging and an enjoyable learning context, and hence improves their learning performance (Hwang, Wu & Chen, 2012; Prensky, 2007; Sampayo-Vargas *et al*, 2013).

More importantly, a significant interaction was found between the gaming and guiding mechanisms on the students' learning motivation. The experimental results revealed that some effective learning supports, such as the multistage guiding mechanism in this study, might decrease students' learning motivation in conventional in-field learning activities. This finding is similar to those reported by several previous studies that students might not realize the usefulness of some learning support and hence could resist acceptance of the support (Charsky & Ressler, 2011; Chu, 2014). For example, the study by Chu (2014) showed that students might feel frustrated or anxious on field trips if they fail to correctly answer the questions raised by the learning system, in particular, when they are asked to answer the same question several times. This could be the reason why the students who learned with the combination of the conventional mobile learning (nongaming) and the multistage guiding mechanism (N-M) showed significantly lower learning motivation than those who learned with the mobile learning approach with single-stage guiding (N-S). Fortunately, the results also revealed that, by leading in the gaming approach, the motivation of the students who learned with the multistage guiding mechanism (G-M) was significantly higher than that of those who learned with the nongaming and multistage guiding approach (N-M), showing that the lead-in of gaming scenarios has great potential for helping students accept those complex but effective learning supports (eg, multistage guiding) in the field. Such a finding also confirms what has been reported by several researchers, namely that educational computer games can improve students' learning motivation if the learning tasks and learning supports are properly embedded in the gaming missions (Hwang *et al*, 2013; Tsai *et al*, 2012).

It should be noted that the experimental results reported in this study were collected from the learning activity of a natural science course for fifth graders; therefore, the findings might not be applicable to other courses or students of other ages. That is, more experiments are needed to investigate the effects of the proposed approach in the future. It is suggested that the integrated gaming and multistage guiding approach can be applied to other in-field learning activities by substituting the learning content and the gaming map with those of the new applications, such as field trips to museums, ecology parks, zoos or science parks. For future research, it would be worth exploring the effects of the approach on the learning performance of students with different personal factors, such as cognitive styles, learning styles or knowledge levels. It would also be interesting to analyze students' learning behaviors in the field. Currently, we are planning to extend the present study to the development of a collaborative mobile learning system, in which students play the game collaboratively as a team to compete with other teams with the multistage guiding mechanism. Moreover, we plan to investigate students' interactive patterns in the new learning scenarios in addition to their learning performance and motivation.

Acknowledgements

This study is supported in part by the National Science Council of the Republic of China under contract numbers NSC 101-2511-S-011-005-MY3 and NSC 102-2511-S-011-007-MY3.

The participants of this study were protected by using a serial number to replace their personal information. They were informed that participation was voluntary and would not affect the grade of the course; moreover, they could withdraw from the study at any time.

The authors are pleased to provide the data of this study upon request. The authors would also like to state that there is no potential conflict of interest in this study.

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