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A Progressive Prompting Approach to Conducting Context-Aware Learning Activities for Natural Science Courses

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Owing to the popularity of mobile, wireless communication and sensing technologies, issues related to contextual mobile learning have widely been discussed in recent years. In the meantime, researchers have indicated the importance of developing effective strategies for guiding students to learn in context-aware learning environments. In this study, a progressive prompt-based context-aware learning approach is proposed to improve the learning performance of students. An experiment was conducted on a natural science course of an elementary school to evaluate the performance of the proposed approach. From the experimental results, it is found that the proposed approach could effectively enhance the learning achievement of the students in comparison with the conventional context-aware learning system with single-stage prompts. It is also interesting to find that the proposed approach, by providing more challenging tasks, encouraged the students to put more effort into examining the contextual information and interpreting the learning content.

RESEARCH HIGHLIGHTS

- A progressive prompt-based strategy is proposed for supporting contextual u-learning activities.
- A contextual learning system has been developed and an experiment has been conducted to evaluate the effectiveness of the proposed approach.
- This approach has been applied to a contextual learning activity of an elementary school natural science course.
- The approach is helpful to students in improving their learning achievement.
- The approach is able to encourage students to put more effort into examining the contextual information and interpreting the learning content during the contextual learning process.

Keywords: ubiquitous and mobile computing systems and tools; empirical studies in ubiquitous and mobile learning; ubiquitous computing; tablet computers; location based services

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1. INTRODUCTION

Recent advancements in computer and communication technologies have enabled researchers to evolve new tactics and tools for providing learning supports, including the use of online discussion forums, knowledge construction tools and synchronous communication facilities in educational settings (Fernández-López *et al.*, 2013; Ruchter *et al.*, 2010; Wang, 2010). Researchers consider such technology-enhanced learning approaches as being promising in terms of helping students enhance their learning performance and develop positive attitudes (Liu, 2009; Looi *et al.*, 2011; Yıldız-Feyzioğlu *et al.*, 2013). On the other hand, scholars have suggested the demand for and importance of situating students in authentic environments in which they can experience and meaningfully learn via linking their prior knowledge with the real-world scenarios when engaging in a task or activity

(Brown *et al.*, 1989; Tsai *et al.*, 2011). This reveals the necessity and importance of developing a series of designed activities for engaging students in learning scenarios that integrate the resources from both real-world and digital-world learning environments (Chen and Huang, 2012; Huang *et al.*, 2011; Martin *et al.*, 2011).

With the emergence and popularity of mobile and wireless communication technologies, learners can be supported while learning anytime and anywhere (Chang *et al.*, 2012; Chen and Huang, 2012; Martin and Ertzberger, 2013; Martin *et al.*, 2011). In the meantime, recent advances in sensing and recognition technologies, such as radio frequency identification (RFID), quick response (QR)-code and global positioning system (GPS), further provide good opportunities for developing technology-enhanced learning systems to facilitate learners to interact with the real-world environment with useful information from the digital space (Chen *et al.*, 2011; Hwang *et al.*, 2011a; Peng *et al.*, 2009); that is, students can be situated in a real-world learning environment and guided by a learning system that provides the right information in the right place at the right time. Researchers have called this 'context-aware ubiquitous learning', 'contextual ubiquitous learning' or 'contextual mobile learning' (Chen *et al.*, 2008; Hwang *et al.*, 2008, 2011b).

Many previous studies have demonstrated the benefits of utilizing mobile and wireless communication technologies in the field trips of various courses, including science, social science and language courses (Chang *et al.*, 2012; Huang *et al.*, 2011; Hung *et al.*, 2010; Looi *et al.*, 2011). For example, Ruchter *et al.* (2010) conducted an environmental education activity in a flood plain using mobile devices with wireless communications to guide the students to observe and discuss. Moreover, Chiou *et al.* (2010) and Chen and Huang (2012) conducted learning activities in a butterfly garden and a museum using mobile and wireless communicating technologies to help students develop knowledge about butterflies and Atayal culture, respectively. Several studies have further reported the helpfulness of using sensing technologies to provide more effective and authentic outdoor learning supports using mobile devices (Lai *et al.*, 2013; Liu *et al.*, 2009; Odić *et al.*, 2013; Wang and Wu, 2011). For example, Shih *et al.* (2012) developed an adaptive u-learning mathematics path system to guide students in their campus mathematics path learning using wireless networks and tablet computers with RFID readers, while Barak and Ziv (2013) designed a context-aware ubiquitous learning environment to facilitate an environmental education course via the use of mobile devices and QR Codes. In comparison with traditional instruction that transfers knowledge to students based on textbook contents, these studies have shown the potential of using mobile, wireless communication and sensing technologies in school settings (Karapanos *et al.*, 2012; Lanir *et al.*, 2011).

On the other hand, researchers have emphasized the significance of providing scaffolding to support specific learning (Chen *et al.*, 2010; Huang *et al.*, 2012). Scaffolding can provide a strategic framework to help students integrate their knowledge (Davis and Linn, 2000; Sharma and Hannafin, 2007). Researchers have argued that prompts, a form of scaffolding, can stimulate meaningful learning and help students realize the relationships between new and old knowledge or experiences (Pressley *et al.*, 1992; Schworm and Gruber, 2012). Several studies further reported that students' learning achievements could be disappointing without effective learning tools, strategies or prompts for guiding them to learn in the field (Chu *et al.*, 2010a; Hwang *et al.*, 2011). Chu *et al.* (2010b) have indicated that students might fail to organize what they have observed in the field along with their prior knowledge without learning supports, since they need to face such complex learning contexts that combine numerous resources from both the digital world and the real world. Therefore, researchers have suggested the importance and necessity of providing proper learning prompts or guidance regarding their responses to assist students in interpreting and organizing what they have learned (Chen *et al.* 2010; Hsu and Tsai, 2013; Huang *et al.*, 2012).

To deal with this problem, a progressive prompting approach is proposed for contextual learning in real-world environments. A contextual ubiquitous learning system has been developed based on the proposed approach. Moreover, an experiment on an elementary school natural science course was conducted to evaluate the effectiveness of the proposed approach by investigating the following research questions:

1. Can the progressive prompt mechanism benefit the students in terms of improving their learning achievement?
2. Is there a significant difference between the students who learned with the progressive prompt-based and the conventional contextual u-learning approaches in terms of their learning attitudes and motivation?
3. Is there a significant difference between the students who learned with the progressive prompt-based and the conventional contextual u-learning approaches in terms of their learning perceptions?

2. LITERATURE REVIEW

Researchers have asserted the importance of providing support to stimulate learners' cognitive development (Chen *et al.*, 2010; Huang *et al.*, 2012). Moreover, prompts can help students identify concepts and construct deeper scientific reasoning (Chen, 2010; Chi *et al.*, 1994). Therefore, prompts have been regarded as an effective instructional means for providing learning supports (Schworm and Gruber, 2012) by engaging students in reflecting on their learning progress as well as helping them stay on track in each part of the learning task (Davis and Linn, 2000; Chen, 2010). In the past decades, prompt mechanisms have been employed for conducting learning activities in different contexts. For example, Wilson *et al.* (2011) applied a prompt mechanism in an activity of learning the scientific concepts of gear movements. They found that prompts reliably induced the students' reflections. Several previous studies have also suggested that affording proper prompts during the learning process has great potential for helping students learn better (Bannert and Reimann, 2012; Yeh *et al.*, 2010).

Owing to the advancements in computer and network technologies, researchers have developed computer-based or web-based learning systems for conducting interactive learning activities. In such technology-enhanced learning environments, students are usually situated in learning contexts that enable them to freely browse the learning content and interact with peers (Hill, 1999). Clarebout and Elen (2006) have indicated that, in such learning settings, students are assumed to be capable of appropriately judging their learning needs and progressively evolving in the learning tasks; however, this is usually not the case. Schwonke *et al.* (2006) have further indicated that it could benefit students more if the learning systems afforded supports to individual students based on their learning progress and status.

Therefore, several researchers have attempted to develop prompt-based systems on the web to help learners construct their knowledge and make reflections during the learning process (Fiorella *et al.*, 2012; Tsai and Tsai, 2013; Yeh *et al.*, 2010). For example, Manlove *et al.* (2007) and Yıldız-Feyzioğlu *et al.* (2013) developed prompt-based systems for natural science courses. Both of these studies reported that such an approach could foster the students' ability to overcome the difficulties of the learning activities and thus promote learning achievement. Researchers have also reported the effectiveness of using prompts in guiding students to cope with difficult learning tasks (Furtak and Ruiz-Primo, 2008; Hwang and Chang, 2011; Orsmond *et al.*, 2004). For example, Diefes-Dux *et al.* (2012) designed formative assessment prompts in a mathematics course to investigate instructor feedback to team responses and found that the perceived quality of student work also impacted the effectiveness of the feedback. Wilson *et al.* (2011) further emphasized that high-level prompts were deeply correlated with high-level responses.

On the other hand, several studies have reported the difficulties of designing effective prompt mechanisms that engage students in learning activities (Schwonke *et al.*, 2006). For example, Furberg (2009) and Horz *et al.* (2009) indicated that students often tend to ignore or neglect prompts, or that students do not benefit from prompts, since they regard them as an irrelevant add-on. Consequently, it is important to have better comprehension of what prompts reflection during learning activities and, in particular, what sorts of learning activities prompt what sorts of reflection (Wilson *et al.*, 2011). Wang (2010) has further pointed out that the graduated provision of prompts can effectively guide students to explore some clues to independently accomplish activities. Several previous studies have also reported the potential of providing prompts or learning guidance in a progressive manner to help students identify their learning problems (Chu *et al.*, 2010a; Tsai and Chou, 2002). Therefore, in this study, a progressive prompting approach is proposed for developing a contextual ubiquitous learning system for guiding students to learn in an authentic activity. Moreover, an experiment was conducted on a Natural Science course of an elementary school to evaluate the effectiveness of the proposed approach.

3. A CONTEXT-AWARE LEARNING SYSTEM WITH A PROGRESSIVE PROMPT MECHANISM

In this study, a progressive prompt mechanism is proposed to support contextual ubiquitous learning activities for elementary school natural science courses. A location-aware ubiquitous learning environment was established with JAVA Eclipse based on the progressive prompt mechanism; moreover, QR-codes are used to enable the u-learning system to confirm the locations of individual students in the field. During the learning activities, individual students are equipped with a mobile device for interacting with the learning system. Figure 1 shows the interface of the learning system for guiding students to find one of the learning targets. When students arrive at the location of a learning target, the system asks them to confirm their location by scanning the QR-code tag on the target with the mobile device. Following this, the students are guided to complete a series of learning tasks via observing the learning targets and answering the corresponding questions.

The process of the progressive prompt mechanism is shown in Figure 2. Initially, students are guided to observe the learning target and answer a series of questions related to the characteristics of the target. If they fail to correctly identify the characteristics, the learning system provides different prompts to guide them to find the correct answer in different stages. The more they fail, the more concrete prompts will be provided to them.

When the students fail to correctly identify a characteristic of the present learning target (i.e., the plant that the students are observing) for the first time, the learning system provides the first-stage prompt. In this stage, the students are guided to observe a comparative target (i.e., the plant with the incorrect characteristic chosen by the students) and to compare the characteristics of the two plants. For example, assume that an incorrect answer 'Tubular flowers' is given by students for describing 'Synedrella nodiflora' in the first stage. The learning system thus guides them to find the comparative plant 'Saluia splendens' that has 'tubular flowers', and asks them to compare the flower shapes of the two plants.

If the students fail to correctly identify the same characteristic of a learning target for the second time, the system provides them with text descriptions of the learning targets as the second-stage prompt. It is expected that the students can find the correct characteristic via comprehending the descriptions.

Figure 1. Presentation of learning information and tasks.

Assuming that the students still fail to correctly identify the characteristic for the third time, the system then provides them with the complete supplementary materials that contain text descriptions and visual information (e.g., images, animations or videos). On the other hand, if the students correctly identify a characteristic, the learning system guides them to observe another characteristic of the same learning target. When all of the characteristics have been correctly identified by the students, the learning system guides them to find and observe the next learning target.

Figure 3 is an illustrative example showing the prompts provided to the two groups. The content of the prompts for the two groups are identical. The only difference is the way of providing the content. For the experimental group, the prompt content is provided progressively. In the first stage, the students in the experimental group are guided to observe a comparative flower with the incorrect feature chosen by the student and compare it with the target flower if they fail to answer the question the first time. In the second stage, text descriptions for each candidate flower are provided and the students are asked to reconsider their answers after reading the descriptions and observing the target flower again. In the third stage, the learning system presents the sketch graph and photograph as well as the text descriptions of the flowers to the students. On the other hand, for the control group, the full prompt content (the third stage prompt) is presented to the students if they fail to correctly answer the question raised by the learning system.

4. EXPERIMENTAL DESIGN

To evaluate the efficacy of the proposed approach, a contextual ubiquitous learning activity was designed for the 'flower characteristics of the plants on the school campus' unit in an elementary school natural science course. The aim of the experiment was to compare the learning achievements, attitudes and motivation of the students who learned with the progressive prompt-based contextual ubiquitous system and those who learned with the conventional contextual u-learning approach.

4.1. Learning environment

The authentic learning environment was a plant garden located in the elementary school in northern Taiwan, as shown in Figure 4. During the learning activity, each student was equipped with a tablet computer for interacting with the learning system. Moreover, each target flower was labeled with a QR code. By guiding the students to find the target flowers and asking them to scan the corresponding QR codes, the learning system was able to confirm the locations of individual students and present corresponding learning tasks and supplementary materials accordingly. In this learning activity, the target flowers were *Pentas lanceolata*, *Stachytarpheta jamaicensis*, *Lantana camara*, *Saluia splendens*, *Synedrella nodiflora*, *Ixeris chinensis*, *Surinam Calliandra*, *Bidens pilosa*, *Angelonia angustifolia*, *Torenia fournieri*, *Allamanda cathartica* and *Bignonia chamberlaynii*.

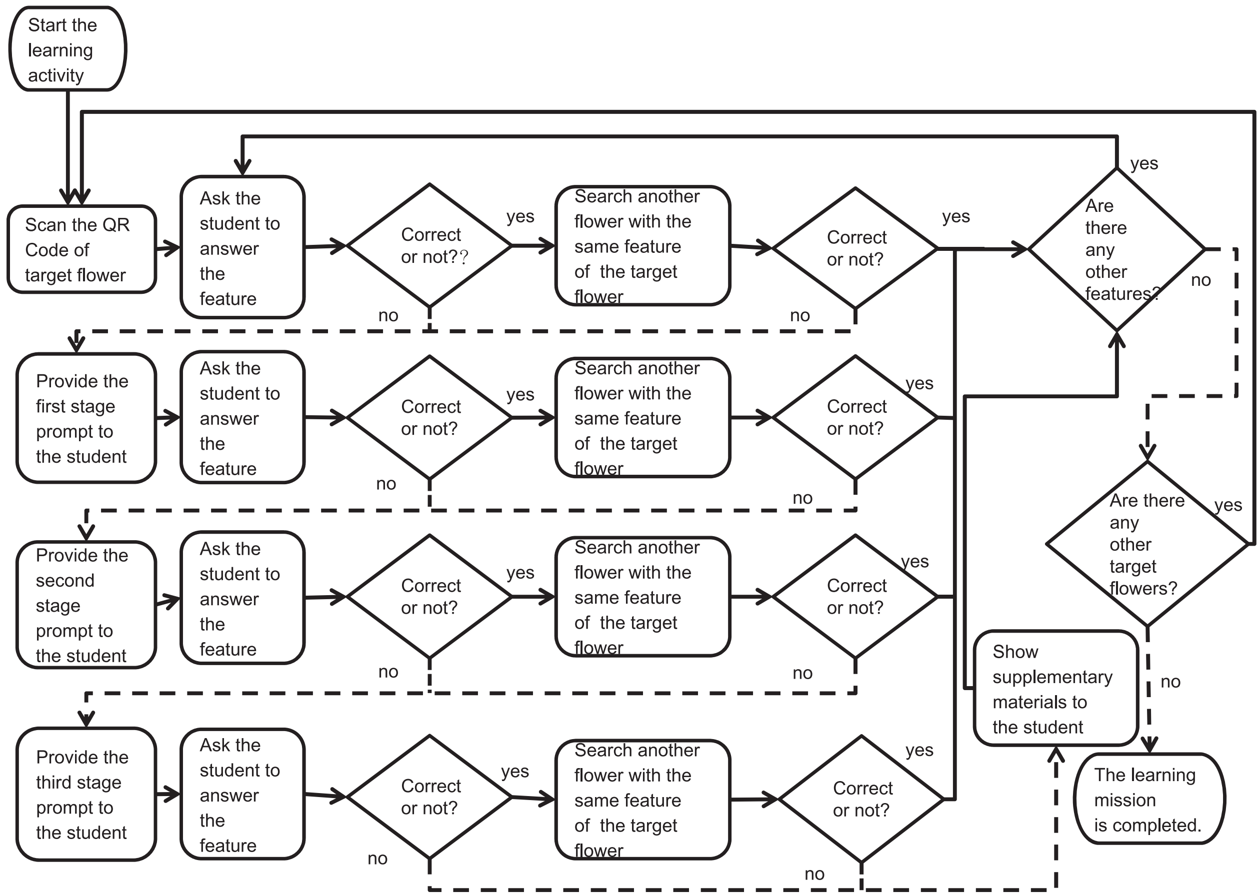

Figure 2. The progressive prompt-based learning guiding mechanism.

4.2. Participants

The participants of the experiment were two classes of sixth graders who studied Natural Science for four hours a week in an elementary school in northern Taiwan. A total of 60 students (32 females and 28 males) participated in this study. One class was assigned to be the experimental group ($n = 31$), and the other class was the control group ($n = 29$). The two classes were taught by the same instructor. None of these students had had previous experience with context-aware/single-prompt/u-learning systems before the learning activity. In addition, to avoid the Hawthorne effect, the two groups were scheduled to visit the campus at different times.

4.3. Experimental procedure

Figure 5 shows the experimental procedure, which consisted of two learning stages. In the first stage, both groups of students were instructed by the same teacher about the basic knowledge of the flowers. Following that, the students took the pre-test and the pre-questionnaires of learning motivation and learning attitudes.

In the second stage, the contextual ubiquitous learning activity was conducted. After practicing the operations of the learning system, the students in both groups were guided by the contextual u-learning system to observe the target plants and complete the learning tasks in 80 min. During the learning activity, the students in the experimental group learned with the progressive prompt-based contextual u-learning approach.

On the other hand, those in the control group learned with the conventional contextual u-learning approach; that is, if the students failed to answer any questions, the learning system would provide prompts with the complete supplementary materials to help them make further observations. Moreover, the learning system would present the next task to the student. Such a context-aware learning approach has been shown to be effective by several previous studies in comparison with traditional field trips guided and instructed by teachers (Chen *et al.*, 2008; Huang *et al.*, 2011).

After the learning activity, all of the students took the post-test and filled out the post-questionnaires for measuring their learning motivation, learning attitudes and learning perceptions. Finally, the researchers interviewed the experimental group students to collect their opinions about the learning approach.

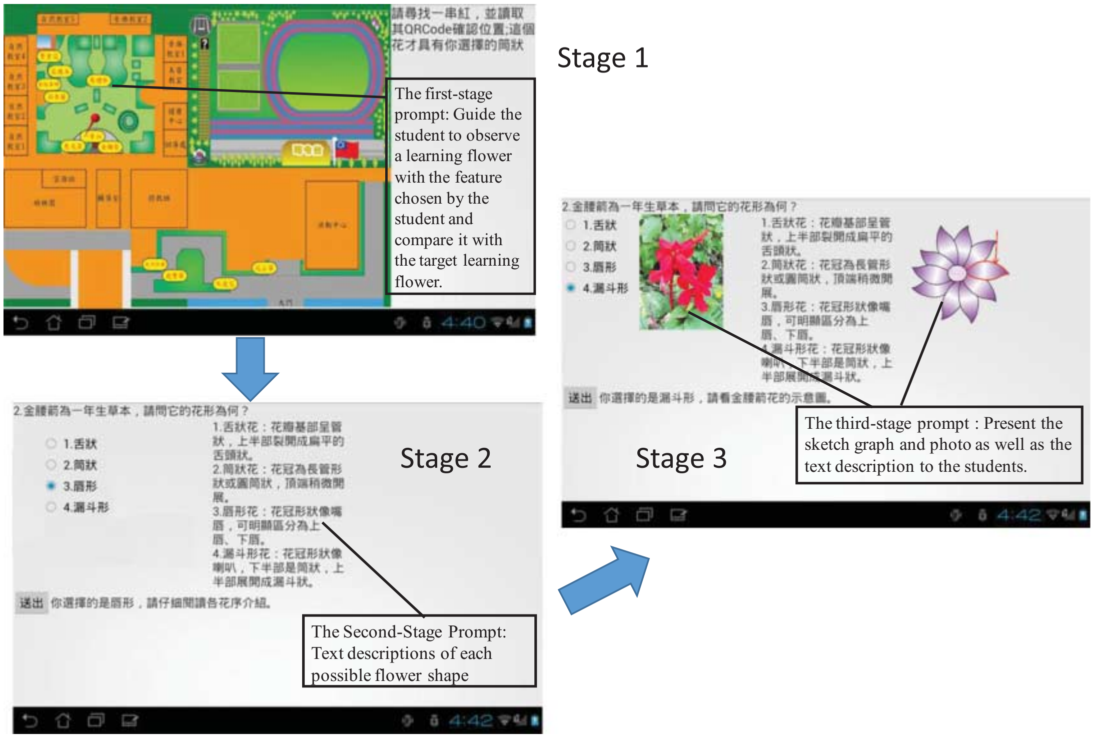

Figure 3. Illustrative example of the prompts provided to the students.

Figure 4. An example of receiving a task, scanning a QR code and executing the task in the learning scenario.

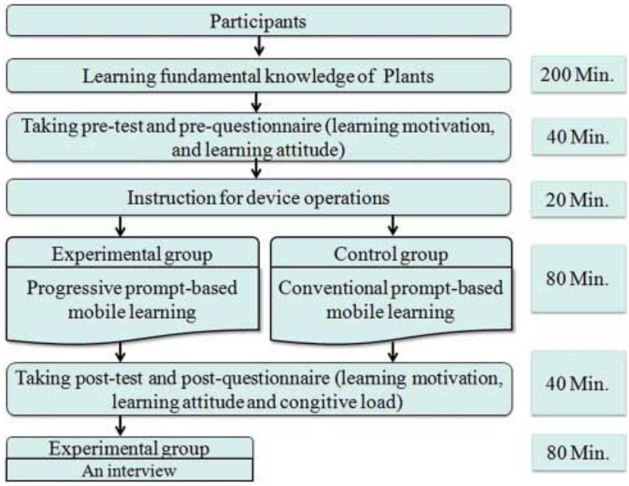

Figure 5. Experimental design of the learning activities.

4.4. Measuring tools

The measuring tools of this study include the pre-test, the post-test, the questionnaires for measuring the students' learning motivation and learning attitudes, and the learning perceptions' measure.

The pre-test aimed to evaluate whether the two groups of students had an equivalent prior knowledge about flowers before participating in the learning activity. It consisted of 39 multiple-choice items with a perfect score of 39. The post-test consisted of ten multiple-choice items (30%), ten matching questions (30%), ten fill-in-the-blank items (30%) and two short answer questions (10%) for assessing the students' knowledge of distinguishing and identifying the flowers. Both the pre-test and post-test were designed by two experts who had more than 10 years' experience of teaching natural science courses.

The learning attitudes' questionnaire was modified from the questionnaire developed by Hwang *et al.* (2013). It consisted of seven items using a five-point Likert scale, such as 'I think taking the flower unit is interesting and valuable' and 'It is worth learning those things taught in the flower unit'. The Cronbach's α value of the questionnaire was 0.79.

The learning motivation questionnaire was modified from the questionnaire developed by Pintrich and DeGroot (1990). It consisted of seven items using a seven-point Likert scale, such as 'I expect I can have good performance in this course' and 'I think this course content is helpful to me'. The Cronbach's α value was 0.86.

The learning perception questionnaire was modified from the measure developed by Hwang *et al.* (2013) based on the items proposed by Sweller *et al.* (1998). It consisted of eight items, including five for the 'task challenge' dimension and three for the 'instruction of the learning content' dimension, based on a seven-point Likert scale. The Cronbach's α values of the two dimensions were 0.85 and 0.86, respectively.

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

Variable	Group	n	Mean	S.D.	Adjusted mean	F
Post-test	Experimental group	31	65.77	19.07	64.46	14.74***
	Control group	29	47.83	19.61	49.24	

***$p < 0.001$.

5. EXPERIMENTAL RESULTS

The collected data were first examined by descriptive statistics to explore the group means, standard deviations and numbers. Then, independent t-tests were performed on the pre-test scores and pre-questionnaire ratings. Moreover, analysis of covariance (ANCOVA) was used to compare the post-test scores and post-questionnaire ratings of the two groups.

5.1. Learning achievement

To compare the prior knowledge of the two groups before the learning activity, an independent t-test was performed on the pre-test scores. The means and standard deviations of the pre-test scores were 27.6 and 5.8 for the experimental group, and 26.4 and 4.7 for the control group. The t-test result showed no significant difference between the pre-test scores of the two groups ($t = 0.876$ and $p > 0.05$). Consequently, it is concluded that the two groups of students had equivalent knowledge about the flowers before participating in the learning activity.

After confirming that the assumption of homogeneity of regression was not violated ($F = 3.64$, $p > 0.05$), the post-test scores of the two groups were analyzed with ANCOVA, in which the pre-test was the covariant, the post-test results were the dependent variable, and the 'different u-learning approaches (two groups)' were the control variable. As shown in Table 1, the ANCOVA result shows that the difference between the two groups was significant ($F = 14.74$, $p < 0.001$) after the impact of the pre-test scores on the post-test was excluded. This implies that the post-test scores of the two groups were significantly different due to the different u-learning approaches. Accordingly, it was concluded that the progressive prompt-based contextual ubiquitous learning system was helpful to the students in terms of improving their learning achievements in comparison with single-stage prompt-based contextual ubiquitous infield learning approaches.

5.2. Learning attitudes and motivation

The assumption of homogeneity of regression was examined for the two groups' ratings of learning attitudes and motivation, and the results showed that the assumption was not violated with $F = 0.27$ ($p > 0.05$) and $F = 0.12$ ($p > 0.05$), respectively;

Table 2. The ANCOVA result of the learning attitudes and motivation post-questionnaire for the two groups.

Variable	Group	n	Mean	S.D.	Adjusted mean	F
Learning attitude	Experimental group	31	3.65	0.72	3.75	0.83
	Control group	29	3.68	0.85	3.57	
Learning motivation	Experimental group	31	5.05	1.14	5.06	0.35
	Control group	29	4.91	1.22	4.90	

Table 3. The t-test result of the learning perception ratings of the two groups.

Variable and source	Group	n	Mean	SD	t
Task challenge	Experimental group	31	4.00	1.39	2.29*
	Control group	29	3.19	1.33	
Instruction of the learning content	Experimental group	31	3.71	1.57	0.897
	Control group	29	3.45	1.58	

$^{*}p < 0.05$.

therefore, ANCOVA was used to compare the learning attitudes and motivation of the two groups after the learning activity by excluding the impact of the pre-questionnaire ratings. As shown in Table 2, the ANCOVA result shows that the learning attitudes and motivation of the two groups were not significantly different from $F = 0.83$ ($p > 0.05$) and $F = 0.35$ ($p > 0.05$) after the impacts of the pre-questionnaire ratings were excluded. This result is reasonable since the students in both groups learned in the contextual ubiquitous environment.

5.3. Learning perceptions

Scholars have indicated that the efficiency of knowledge acquisition and construction is highly related to the difficulty levels of the knowledge and the way the learning materials are presented (Verhoeven *et al.*, 2009). Therefore, it is worth investigating the perceptions of the students who learned with the different approaches. In this study, the learning perception measure was used to compare the students' perceptions of the task challenge and the way the learning content was instructed.

Table 3 shows the independent t-test results for the 'task challenge' and instruction of 'the learning content' scores of the two groups. For the 'instruction of the learning content' dimension, the means and standard deviations were 3.71 and 1.57 for the experimental group, and 3.45 and 1.58 for the control group. No significant differences were found between the 'instruction of the learning content' ratings of the two groups with $t = 0.897$ and $p > 0.05$.

On the other hand, for 'task challenge', the means and standard deviations were 4.00 and 1.39 for the experimental group, and 3.19 and 1.33 for the control group. The t-test result shows that the 'task challenge' of the experimental group is significantly higher than that of the control group ($t = 2.29$, $p < 0.05$).

Table 4. Average number of students who passed each prompting stage.

Group	n	1st stage	2nd stage	3rd stage
Experimental group	31	4 (13%)	12 (39%)	15 (48%)

Table 4 shows the average number of students who passed each prompting stage. It is found that only 12% and 39% of the experimental group students passed the first and the second stages, respectively. Nearly half (48%) failed to pass the first two stages, and required the assistance of the complete prompt to find the correct answers during the learning activity. This conforms to the finding from the task challenge ratings, which shows that the experimental group students faced more challenging tasks than those in the control group.

5.4. Interviews

To obtain more detailed feedback from the participants, nine students in the experimental group (three each of the high-, medium- and low-achieving students) participated in independent, semi-structured interviews carried out by one researcher of this study. The interview questions, which were modified from the questionnaire developed by Hwang *et al.* (2009), were related to their perspectives on the progressive prompt-based contextual u-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?' All of the interviews were recorded by a digital device. After that, all relevant data were transcribed and analyzed by the researchers.

The interview records were analyzed based on the grounded theory of quantitative analysis (Glaser and Strauss, 1967), which is a qualitative research approach consisting of three steps, that is, coding (i.e., categorizing qualitative data), memoing (i.e., recording the key points related to the learning approach) and summarizing and generalizing (i.e., summarizing the key points and finding the implications of the interview).

From the interview results, it was found that the students shared some positions; that is, they considered the helpfulness of the approach as 'providing helpful prompts', 'encouraging clue-seeking' and 'inspiring reflection'.

From the perspective of 'providing helpful prompts', all of the students indicated the benefits of the prompts provided by the learning system in terms of helping them complete the learning tasks by themselves. For example, one student mentioned that, 'I keep concentrating on the prompts provided by the system. The prompts help everyone complete the learning tasks'. Such a finding is not obvious since previous studies have reported that students often tend to ignore prompts given by the system if they find that they are not helpful (Furberg, 2009).

From the 'encouraging clue-seeking' perspective, all of the students shared the same opinion that they felt more impressed when looking at learning targets in the field and searching for answers by themselves. Seven of the students indicated that they were situated in challenging learning scenarios when learning in the field with the progressive prompt approach. One of the students stated that, 'the system did not give me the answer; instead, it showed me where to obtain more information via observing flowers in the real-world environment. Such a prompt engages me in observing and thinking more'. Another student further stated that, 'It is very interesting to think what the prompts mean. I enjoy the challenges and like to find the answers with the help of the prompts'.

In terms of 'inspiring reflection', all of the students indicated that the progressive prompts engaged them in reflection during the learning activities. Five of the students further emphasized the importance of reflecting immediately when they were learning in the field with the help of the prompts provided by the learning system. One student stated that, 'Without the help of the prompts, I would have been unable to find the mistakes I made immediately. I might not have been able to recall what happened or find the correct answers at a later time if the prompts were not provided instantly'. Another student further indicated that 'Without the prompts, I might think that I was right. I am happy that I have found the correct answers following the prompts'. Such a finding conforms to what has been reported by Davis and Linn (2000) that the provision of prompts is helpful to students in encouraging them to make reflections during learning processes.

6. DISCUSSION AND CONCLUSIONS

The aim of this study was to employ a progressive prompt strategy to assist students in identifying the characteristics of flowers in the real world, and to organize what they observed in the field with their prior knowledge. In addition, a contextual ubiquitous learning activity has been conducted on an elementary school natural science course to evaluate the effectiveness of the innovative approach by comparing the learning achievements, learning attitudes and learning motivations of the students. The results indicated that the progressive prompt-based contextual ubiquitous learning approach is of great benefit to the students in terms of promoting their learning achievements in the authentic learning activity. The results of this study are consistent with several previous studies, suggesting the importance and necessity of providing effective learning support during contextual ubiquitous learning activities (Liu *et al.*, 2009; Wang and Wu, 2011).

In the interviews, the students mentioned that the progressive prompt-based contextual ubiquitous learning approach provided them with progressive prompts, encouraged them to seek clues and engaged them in making instant reflections. This could be one of the reasons why the learning achievements of the experimental group were significantly better than those of the control group. It also conforms to what has been reported by Wilson *et al.* (2011) that reflection may assist students in developing their comprehension of scientific concepts.

In the meantime, the medium task challenge of the experimental group students also showed that the progressive prompt approach provided the students with more challenging tasks, which encouraged them to put more effort into thinking and finding the answers by having them face more challenges in the first and second prompt stages. On the contrary, the relatively lower task challenge for the control group students showed that the conventional contextual u-approach that provided rich information eased the students' load of finding information, while decreasing the task challenge and required effort. As indicated by several researchers, situating students in learning scenarios with moderate task challenge is beneficial with regard to inspiring them to learn, implying that students could reveal good learning performance when the task challenge reaches an appropriate level (Hwang and Chang, 2011; Sweller *et al.*, 1998).

Although the progressive prompt-based contextual u-learning approach was implemented in the learning system for conducting plant characteristic identification activities, it can be applied to other courses or subject units that aim to engage students in field trips for observation and characteristic identification, such as geology exploration or rock identification activities for geoscience courses, problem-based activities for local culture courses or art courses, and other feature identification activities for natural science courses. Even so, the limitations of adopting this approach need to be noted; that is, it could be time consuming for researchers or teachers to prepare the contents of the progressive prompt-based mechanism for a new application. In the future, we plan to explore the efficacy of applying this mechanism to other courses and other graders by taking more personal factors into consideration, such as the students' knowledge levels, learning styles and cognitive styles. Moreover, it is worth investigating the factors that might affect students' learning performance and attitudes in depth by interviewing those students who learn with different prompting approaches.

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APPENDIX

Questionnaire of learning perceptions

Task challenge

1. The learning tasks in this learning activity were difficult for me.
2. I had to put a lot of effort into answering the questions in this learning activity.
3. It was difficult for me to answer the questions in this learning activity.
4. I felt frustrated answering the questions in this learning activity.
5. I did not have enough time to complete the learning tasks in this learning activity.

Instruction of the learning content

1. During the learning activity, the way of instruction or presentation caused me a lot of load to comprehend the learning content.
2. I needed to put lots of effort into understanding the instruction of the content during the learning activity.
3. The instructional approach in the learning activity was difficult to follow and understand.