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An investigation of attitudes of students and teachers about participating in a context-aware ubiquitous learning activity

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Abstract

In recent years, digital learning has been converting from e-learning to m-learning because of the significant growth of wireless and mobile computing technologies. Students can learn any time and any where with mobile devices. Consequently, context-aware ubiquitous learning (u-learning) is emerging as a new research area. It integrates wireless, mobile and context awareness technologies in order to detect the situation of the learners and provide more seamless adaptive support in the learning process. In this paper, a context-aware u-learning environment is developed for learning about campus vegetation in elementary schools based on an innovative approach by employing repertory grid method in designing learning content. In addition, we probe the feasibility of context-aware u-learning in courses by soliciting feedback from the students and teachers through interviews and questionnaires. The findings reveal that the environment is capable of enhancing students' motivation and learning effectiveness. Moreover, it is also capable of reducing the teaching load while enabling better control of class order.

Introduction

Mobile learning (m-learning) has been regarded as the advanced model following e-learning. Georgiev, Georgieva and Smrikarov (2004) defined it as the new stage of digital learning. It uses mobile devices, such as personal digital assistants (PDAs), mobile phones, portable computers and so on. It can be seen as part of ubiquitous computing that integrates mobile computing, context-aware mechanisms and pervasive computing technologies in our daily lives.

Because of its high mobility and spontaneity, m-learning offers learners access to learning objects and resources that are distributed around us. In the 'anytime, anywhere' learning era, what really matters is whether students can access the right resources at the right time in the right place. Learners should be able to interact with the learning objects both in the real world and in the virtual world. Apart from that, the ultimate goal of m-learning is to enable mobile devices to offer individualised guidance and support during the learning process, and replace the one-size-fits-all receptive style of learning. It enables students to walk out of the classroom and actively explore their learning environment to gain more experience in collaboration and problem solving.

In addition to the use of mobile technology, this study uses radio-frequency identification (RFID) to facilitate the context-aware mechanism, and enhances ubiquitous learning (u-learning), making it ambiently intelligent. Researchers in recent years have demonstrated the benefits of applying wireless communication and mobile and sensor technologies to outdoor learning activities (see, for example, Chen, Chang & Wang, 2008; Chen, Kao & Sheu, 2003; Chu, Hwang, Huang & Wu, 2008; Ogata & Yano, 2004). Such a learning environment is able to sense the situation of learners and provide adaptive support, and has been referred to as 'context-aware ubiquitous learning' (Hwang, Tsai & Yang, 2008b).

Taking a fifth-grade natural science course in elementary school as the educational implementation target content, this research uses a 'Campus Plants and Ecology' unit as an example to design a complete mobile learning course. This course allows students to use PDAs to explore their campus without needing direct help from the teacher, and to actively observe various kinds of plants and their features.

Moreover, this study uses the repertory grid method, invented by George Kelly (1955), to assist the teacher or domain expert in designing the learning content. Such an innovative approach enables the environment to be an expert system that guides students' learning and assists students in constructing their learning in a structured way. The research question of this study rests on whether this innovative approach can successfully enhance students' learning attitude and effectiveness. Consequently, the effectiveness of this u-learning design was assessed with the help of a questionnaire and interview-based survey of the students and the teachers who participated in the course. The survey solicited their feedback on their learning motivation, learning conditions and learning satisfaction.

Literature review

Ubiquitous learning

Ubiquitous computing is being widely adopted in education to create all-time learning environments (Casey & Mifsud, 2005). By adding context-awareness functionality to u-learning, the learning environment can further detect learners' learning conditions, including locations, actions, weather conditions, time and so on (Kawahara, Minami, Morikawa & Aoyama, 2003).

Cheng, Sun, Kansen, Huang and He (2005) proposed the four steps of u-learning services that include setting individualised instructional goals, sensing learning behaviours, comparing learning behaviours to instructional requirements and offering personalised support. Furthermore, Hwang *et al* (2008b) proposed context-aware u-learning characteristics that include the ability to detect learners' conditions and surroundings, the ability to actively and accurately provide personal assistance according to their learning context, the ability to facilitate seamless learning where learning would not be discontinued due to location changes, and the ability to adapt to different mobile devices and various functions.

Such adaptation and personalisation for individual learners requires continuous monitoring of the learners and is typically done by frequently updating their personal records in the database (Hwang, Tseng & Hwang, 2008a). In designing such a database, in order to establish assessment and evaluation in the u-learning environment, there is a need to define reference variables. Five situation variables have been identified for providing appropriate learning in the real world (Hwang *et al*, 2008b):

1 Personal situation: This includes location, arrival time, body temperature, heartbeat, blood pressure, etc.
2 Learning environment: This includes sensor ID, location, temperature, moisture, air gradient., approaching objects, etc.
3 Device detection data: This includes data sensed from target objects, such as temperature, acidity, contamination density, shape and colour of trees.
4 Learning profile: This includes learners' data and learning processes, predefined agendas, online discussion content, start and end times, attention span, learning order and limitations to learning activities, etc.
5 Environmental data: This includes location descriptions, regulations, user records, equipment and facilities, management information, users, etc.

Hwang *et al* (2008b) asserted that context awareness and action initiative are the two major differences between m-learning and context-aware u-learning that enable the system to train and evaluate the real-world observation skills and problem-solving abilities of the learners.

With respect to the retrieval and application of context-aware technology, some scholars have been devoted to the development of context-aware technologies (eg, Mostéfaoui, Bouzid & Hirsbrunner, 2003), whereas others have proposed peer-to-peer learning platforms (eg, Yang, 2006), using user location and condition as the primary retrieval data (eg, Isoda, Kurakake & Nakano, 2004), and using active spaces to detect users' locations (eg, Christopher & Roy, 2003). Meanwhile, many others have conducted implementation evaluations; for example, Ogata and Yano (2004) developed a Japanese language learning system; Joiner, Nethercott, Hull and Reid (2006) used SoundScape to construct a guiding system; Chen, Chen, Tsai, Li and Chen (2008) developed a customisable learning system; and Rogers *et al* (2005) conducted the Ambient Wood project in which u-learning becomes a type of learning that integrates indoor and outdoor experiences.

Among the previous research works in the literature, we found that the design of u-learning activities is seldom the focus, and developers lack related knowledge when building such systems. Therefore, this research not only develops a context-aware u-learning system, but also implements an expert system to assist the design of learning activities related to campus plants.

Learning attitude

Attitude is defined as the state of mind and feeling that influences how people think and behave. Webster's Dictionary defines it as 'a mental position with regard to a fact or state'; that is, it is a complex mental state involving beliefs and feelings and values and dispositions to act in certain ways. Learning attitude, on the other hand, refers to how the way students feel and think influences their learning status, opinions and behaviour.

The research of Rau, Gao and Wu (2008) showed that 'motivation and pressure are considered two factors impacting vocational senior high school student learning'. On the other hand, Triantafillou, Georgiadou and Economides (2008) also concluded from their research that 'small group evaluation can offer useful implementation information concerning the usability and the appeal of the system. Usability is a measure of the ease with which a system can be learned and used'. The usability and the appeal of their system were investigated through attitude questionnaires and a debriefing session. Evans (2008) utilised a 5-point Likert scale questionnaire to compare students' attitudes to lectures, podcasts, notes, textbooks and multimedia e-learning systems, and also had positive results for the m-learning podcast integration into learning. Moreover, according to the factor analysis results of web-based collaborative learning systems for knowledge management by Liaw, Chen and Huang (2008), 'five attitude factors including system functions, system satisfaction, collaborative activities, learners' characteristics, and system acceptance should be examined at the same time when building a Web-based collaborative learning system'.

However, the studies just mentioned were carried out at either college or high school level, and the emphases were mainly on the development and implementation of conventional web-based learning systems. From their experiences, this study aims to experiment at the elementary level, and analyse whether students' learning attitudes would change throughout the process in a context-aware u-learning environment.

Research method

In this research, an elementary school was invited to join as a partner. A natural science course was used as the content subject, and students were invited to participate in the Campus Plants Learning Activity (CPLA). Figure 1 shows the learning process for developing the context-aware u-learning environment on the campus. In CLPA, the target learning objects (plants) were labelled with RFID tags, and each student had a mobile device (PDA) equipped with an RFID reader. Every student was guided by their PDAs to observe the target plants on campus. Once the RFID reader sensed the target

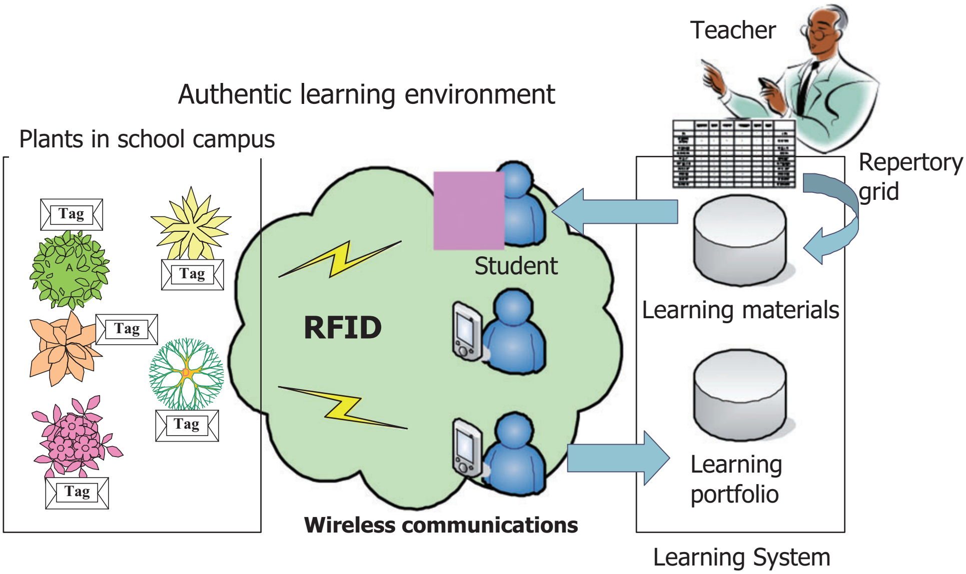

Figure 1: Structure of the context-aware u-learning system

objects, the system actively provided related information, and directed the students to make detailed observations through a series of questions-and-answers.

Thirty-four fifth-grade (11 years old) students with gender evenly distributed participated in this experiment. They were from the same class, and all had attended other courses related to campus plants taught by the same teacher. Before the experiment, the students were taught to use the PDAs with RFID sensors. The experiment lasted 2 weeks. Every day five students explored the campus with their PDAs for 1 hour. After the learning experiment, the students filled out a questionnaire that compared what they thought and did before, during and after the learning activity. The questionnaire mainly focused on the students' feelings about using the mobile device, about the mobile learning approach and their overall personal opinion about whether the use of the PDA had changed their learning behaviour.

Development of the learning environment

The context-aware u-learning environment was established with a PDA for each student, which could detect the RFID tags that were preinstalled around the campus. The students used the PDAs to retrieve learning materials through the wireless network. The content was presented through a web browser. The students' learning process and progress were recorded in real time in the learning system (Figure 1).

Because of the PDAs' small screens, the learning content was designed with a few considerations in mind, as suggested by Churchill and Hedberg (2008), which included:

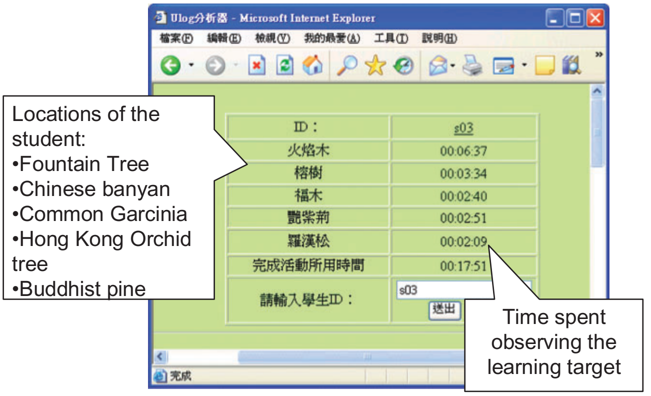

Figure 2: Illustrative example of a context-aware u-learning portfolio

being useful in the appropriate context, providing the most information in the limited space, using simple touches or clicks to manipulate the system instead of complicated input methods, avoiding using scrolling, allowing information to be presented on a single screen view, and using short words to lighten cognitive load.

In order to realise the seamless learning ideal of u-learning, the learning system is required to generate appropriate feedback for the users at the right time. By knowing students' learning conditions, the system is expected to properly guide students for the next action. Its main tasks include acting as a web server to provide learning materials to the client end, building a database server to record users' learning processes, establishing and editing plant learning materials, saving and retrieving a repertory grid, recording students' learning condition, and providing a log analysis interface so that teachers can perceive students' learning difficulties by observing the time spent on each target object (Figure 2).

Strategy of designing learning content

A repertory grid-oriented approach is used to guide the teachers and plant experts to classify the characteristics of the campus plants. The repertory grid technique is widely used in many fields such as decision making, medical, psychology, monitoring, diagnosing and training activities (Chu & Hwang, 2008; Hwang, Chen, Hwang & Chu, 2006). It originated from Kelly's personal construct theory (Kelly, 1955), which aims to elicit and analyse knowledge by identifying different concepts in a domain, and distinguishing among them.

A repertory grid is represented as a matrix whose columns have element labels and whose rows have construct labels. An element might represent a concept to be learned, a decision to be made, an object to be classified or a goal to be achieved, and a construct consists of a trait and the opposite of the trait; therefore, a grid represents a class of

Table 1: Illustrative example of a repertory grid for the 'campus plant and ecology' unit

	E1	*E2*	*E3*	*E4*	*E5*	*E6*	
Tall	3	1	5	3	2	5	Short
Oval-shaped leaf	5	2	3	1	1	5	Heart-shaped leaf
Leathery texture	1	1	1	1	1	5	Not leathery texture
Rounded edge	1	2	3	1	1	5	Sawtooth edge
Smooth leaf surface	1	1	2	1	1	5	Rough leaf surface
Has prop root	2	4	5	5	1	5	Does not have prop root
Thick trunk	1	2	4	4	1	4	Thin trunk
Has syconus	1	4	5	5	1	5	Does not have syconus
Has syconium	1	1	5	5	1	5	Does not have syconium

objects, or individuals, and the value assigned to an element–construct pair reflects the relationship of that element and construct.

Table 1 shows an illustrative example of a repertory grid for the 'campus plant and ecology' unit. In each cell of the grid, the teacher or domain expert is guided to fill in the degrees of each element in terms of the construct from 1 to 5, where 1 refers to a positive trait, 2 signifies a partial positive trait, 3 is unknown or of no relevance, 4 is a partial opposite trait, and 5 means the opposite trait. In this example, E1, E2 ... E6 represent Botree, Camphora tree, Orchid tree, Formosan Nato tree, Chinese Banyan and Common Mulberry respectively.

Once the repertory grid is constructed, a similarity-analysis formula is invoked to analyse the degree of similarity between each pair of elements (Gaines & Shaw, 2005):

$$\text{Similarity}(E_A, E_B) = 1 - \frac{\sum_{i=1}^{N} |RG(E_A, C_i) - RG(E_B, C_i)|}{Max\_Difference} \times \frac{1}{N} \times 100\%$$

where N is the number of elements (learning objects) and *Max_Difference* is the maximum difference between two ratings (in this case, $K = 5 - 1 = 4$), and RG (E_A, C_i) represents the rating for element E_A and construct C_i.

Figure 3 shows the analysis results by applying the RepGrid (Gaines & Shaw, 2005) to analyse the traits of the six plants. The left part of Figure 3 depicts the degree of similarity between each pair of elements, and the right part is a two-dimensional map that provides a global view of the relationships among the elements. In this example, it can be seen that some elements are very similar; that is, they are difficult to distinguish based on the existing constructs.

If the similarity value between two elements is too high, an additional construct is suggested by the expert for the second time to distinguish these two elements. For

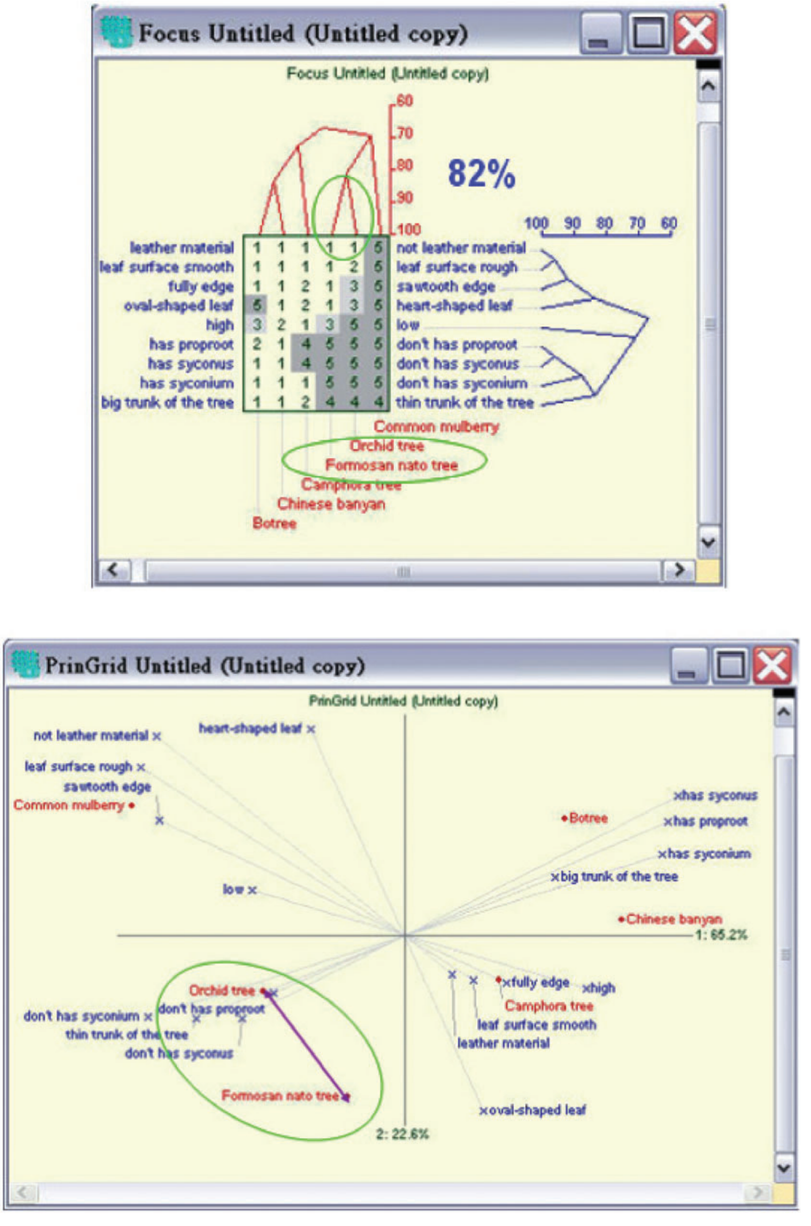

Figure 3: Results of the first-round analysis

example, in Figure 3, it is found that the similarity degree of Orchid Tree and Formosan Nato tree is 82%, which shows that the difference between the definitions of traits is insufficient. The expert is therefore asked to add a construct (ie, 'egg-coloured leaf') to distinguish between them. Consequently, the similarity analysis result of the two

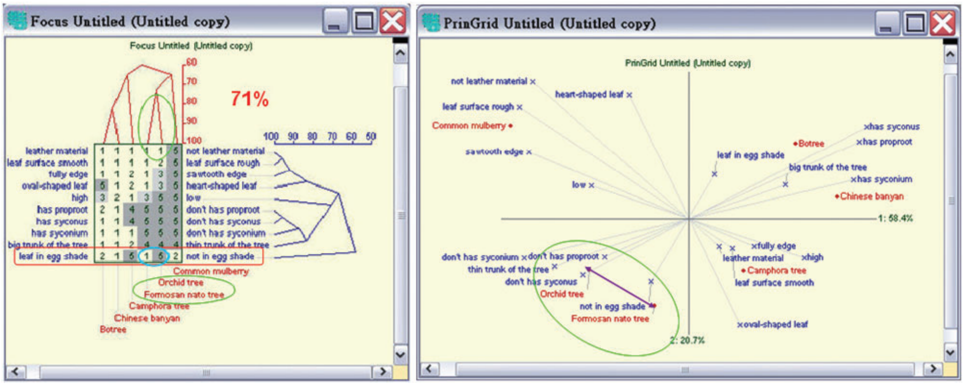

Figure 4: Results of the second-round analysis

elements becomes 71%, as shown in Figure 4; that is, by adding traits to distinguish the two plants, the result becomes much more satisfactory.

Questionnaire design

To assess the effectiveness of this u-learning design, and consequently to know students' responses to the use of mobile devices and their feelings about the course, a questionnaire was distributed to the students who participated in the activity, followed by interviews (as shown in the Appendix).

The questionnaire items for this study were developed based on the questionnaire proposed by Chu *et al* (2008). The original version of the questionnaire had a reliability coefficient (Cronbach's alpha) of 0.829. In this study, the revised questionnaire consists of 28 items which use a 5-point Likert scale. The questionnaire was designed to investigate the attitude of the participants towards the context-aware u-learning activities. The reliability coefficient of this questionnaire is 0.904. It contains three sets of questionnaire items. The first set is related to students' interests and habits, and experiences in using computers and PDAs, as well as the instructional styles of teachers, before experiencing this u-learning activity. The second set asks questions about how students used the PDAs during the u-learning process and whether their attention and attitude become more positive because of such learning activities. The third set of questions is related to the students' learning results, their satisfaction level and the reasons why they liked or disliked learning with the mobile devices.

Learning scenario

As the natural science course usually requires a fair amount of physical observation or equipment manipulation, a course design with field activities and technology integration is appropriate. In this study, the learning activities are focused on leaf shape, leaf edge, leaf phyllotaxy and flower because they are more obvious during observation, and they can offer quick identification of the plants. The extended learning materials intro-

Figure 5: Campus environment and learning scenario

duced other plants in the same family and their identical traits. In the learning process, students could take notes for review. The goal was to stimulate a positive learning attitude among the students and enable them to finally generate strategies for distinguishing between plants. The learning objectives included 'knowing the names and traits of the campus plants', 'identifying the functions of leaves in daily life', 'tasting the flavour of tea', 'knowing whether leaves distend with water', 'being able to conduct critical observation', 'using their own language to introduce plants' and 'increasing learning motivation and interest'.

Nine constructs were predefined by content experts so that the students were guided to observe and compare the six campus plants. The campus environment and learning scenario are shown in Figure 5.

The students equipped with PDAs were guided by the learning environment to observe the target plants after logging into the system. As shown in Figure 6, a campus map was displayed on the screen of the PDA to show the location of the next plant to be observed.

In addition, a textual description and a simple photo were provided as hints to assist the students in finding the target plant, as shown in Figure 7.

As the student found the target plant and walked up to it, the RFID sensor detected the signal from the tag on the plant. Once the learning system received the signal from the tag of the target plant, supplemental materials concerning the plant were provided (as shown in Figure 8).

Consequently, the learning system guided the students to observe and identify the minute details of each target plant, for example, the leaf shape, leaf edge, leaf phyllotaxy and the growing order of flowers on the branches. Figures 9 and 10 show illustrative examples of guiding the students to observe and identify the leaf shape and the growing order of flowers on the branches of the target plant.

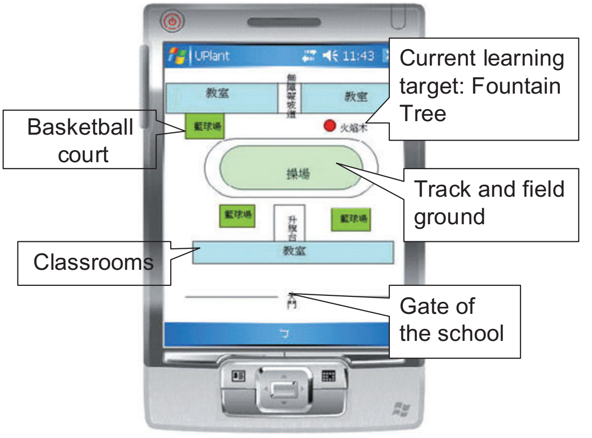

Figure 6: Location of plants observed

Figure 7: Basic knowledge of plants

After completing the observation of a target plant, the learning system provided a digital notebook, reminding students to take notes, as shown in Figure 11.

Research findings

Survey of the effects on learning attitudes

In this research, we obtained questionnaire results from 34 students. The survey was designed using a 5-point Likert scale. It should be noted that the survey used in this study was originally in Chinese. The wording of the survey was designed to be easily

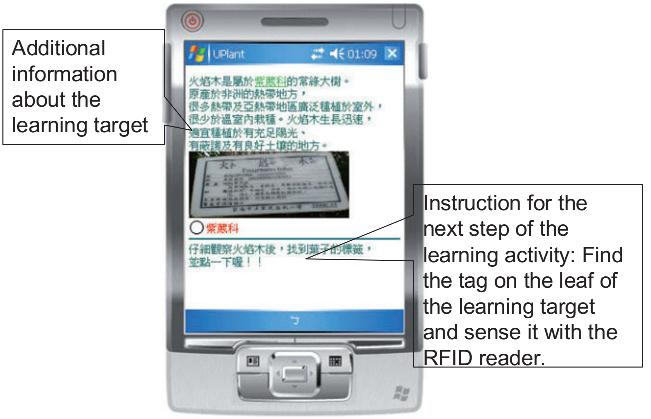

Figure 8: Supplemental materials about the target plant

Figure 9: Observing and identifying the leaf shape of the target plant

understood by fifth-grade students. Any replication of this study should consider revising the survey questions to meet the comprehension needs of the participants.

The average score of the students' technology use experience before taking the course was 3.49. Students had medium experience of using PDAs, digital cameras and the Internet, and had used some of those tools to learn about plants before this experiment. In terms of students' fondness of learning about plants and use of the PDAs, the average score 4.24. The students liked to observe plants and liked to use the PDAs in their learning. They thought that using PDAs in learning could enhance their learning attitude, as was revealed by a score of 4.50. They also thought that using PDAs was convenient and easy, as indicated by the scores of 4.53 and 4.44 respectively.

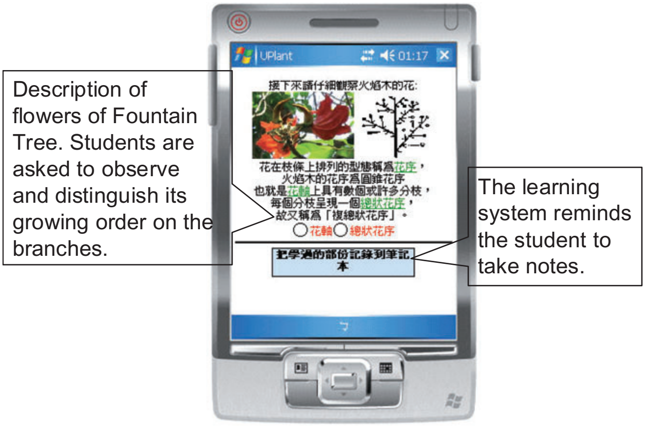

Figure 10: Learning about flowers

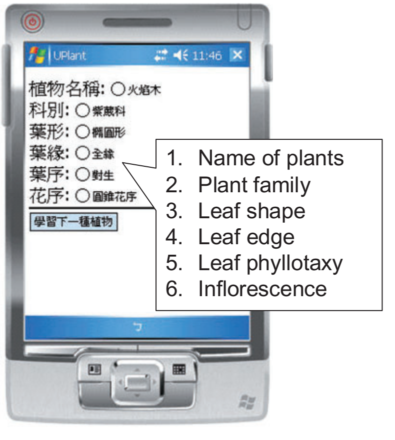

Figure 11: Contents of the learning notebook

After the course, the average satisfaction score was 4.43. The majority of students (4.76) thought that learning with PDAs was much more interesting than traditional learning and that the learning experience was more liberating and pleasant (4.76). The majority (4.71) were happy to have this experience. Therefore, most students were willing to spend time after class to learn about the plants in the campus (3.65).

Afterwards, we interviewed eight randomly chosen students and three teachers who participated in this project, to elicit further explanations. Half an hour was taken for each interview with an average of 18 open-ended questions. One teacher was responsible for the campus plant encyclopaedia and taught a plant-related course. The second teacher taught information technology. The third teacher was the class teacher who led the experiment and taught a plant-related course.

Of the interviewed students, 85% thought that the PDAs could enhance their learning attitude, but with one student observing that the teacher's explanation is more structured and complete. This phenomenon corresponded to our interviews with teachers that revealed the need to increase the richness of the content provided by the u-learning system. Ninety-one per cent of the students mentioned that they would try to use the PDAs to search for relevant materials. Ninety-one per cent of the students also thought that learning with the PDAs was convenient, and 82% thought that it was easy to learn with them. Regarding ease of use, students reported that using the automatic RFID sensing mechanism to retrieve learning materials was easier than inputting or selecting data. Other than that, we observed that although the students were learning individually with the PDAs, they often discussed the content with their classmates in the process. During the interviews, some students said that it would be more interesting to learn in groups, and some teachers said that group activities and competitions have the potential to make learning pleasurable. Ninety-seven per cent of the students agreed that using PDAs to learn was much more interesting than learning in the traditional way. PDAs make learning more liberating and less pressured since the teacher is not around. Observation activities could increase the students' experience of real objects and avoid them being misguided by pictures. Ninety-one per cent of the students agreed that one-to-one PDA guidance was easier to understand than group learning from the teacher's class because they could control their own learning speed and could remedy the neglect and isolation typically present in large group teaching. Ninety-one per cent of the students also thought that learning with PDAs could enhance their learning attitude. Seventy-nine per cent of the students said that they would recommend the PDA-based learning environment to other classmates. However, the occasional instability of the PDAs often hindered the smoothness of the learning and made the learning intermittent.

An analysis of the learning logs from the system revealed that the students had to spend nearly half an hour to finish learning about six campus plants. No significant difference in learning time between high- and low-achievement students was found.

Learning attitude assessment

The findings of the study were validated by statistical analysis. Table 2 shows the paired t-test results for three attitudinal questions, including 'Interest in plant observation ($t = -4.941$, $p < 0.001$)', 'Interest in this course ($t = -4.755$, $p < 0.001$)' and the 'Motivation of learning ($t = -5.048$, $p < 0.001$)', of the students.

The values of Cohen's d (Cohen, 1988) for the questions 'Interest in plant observation', 'Interest in this course' and 'Motivation of learning' are 1.05, 1.18 and 1.09 respectively, which shows a large effect size (Cohen defined effect sizes as 'small, $d = 0.2$', 'medium, $d = 0.5$' and 'large, $d = 0.8$'). Moreover, these effect size values, ie, 1.05, 1.18 and 1.09, indicate that the means of the treated group for the three attitudinal ques-

Table 2: Paired t*-test result and effect size for the feedback from students (*n *= 34)*

Questionnaire items		*Mean*	n	SD	t	*Significance (two-tailed)*	*Effect size*
Interest in plant observation	Before	3.265	34	1.377			
	After	4.500	34	0.929	−4.941*	0.000	1.05
Interest in this course	Before	3.529	34	1.331			
	After	4.735	34	0.567	−4.775*	0.000	1.18
Motivation of learning	Before	3.265	34	1.377			
	After	4.441	34	0.660	−5.048*	0.000	1.09

*$p < 0.001$.

*Table 3: Independent t-test result and effect size for high- and low-achievement students on 'Motivation of learning' (*n *= 34)*

	F	*Significance*	t	df	*Significance (two-tailed)*	*Mean difference*	*Standard error difference*	*Effect size*
Equal variances assumed	0.071	0.791	−2.521*	32	0.017	0.529	0.210	0.86
Equal variances not assumed			−2.521	31.804	0.017	0.529	0.210	

*$p < 0.05$.

tions are at the 85, 87.6 and 85.8 percentiles of the untreated group respectively. That is, the u-learning approach with sensor technology and repertory-grid method is helpful in improving the learning attitude of students in terms of these three aspects.

We further divided the whole class into high- and low-achievement groups according to their academic performance in terms of average scores for the natural science course. The independent sample *t*-test was conducted to see whether students' 'Motivation of learning' in u-learning showed differences (as shown in Table 3). It was found that context-aware u-learning is more helpful to low-achievement students than to high-achievement students (with $p = 0.017 < 0.05$) in terms of the 'Motivation of learning' aspect. Overall, the findings revealed that students' learning motivation was improved. Both the *t*-tests of learning motivation of the high- and low-achievement students achieved significant results. Apart from that, the results suggest that low-achievement students have greater improvement than high-achievement students. Moreover, Cohen's *d* is 0.86 in this test, which indicates that the mean of 'Motivation of learning' for low-achievement students is at the 81 percentile of the high-achievement group.

Table 4: Paired-t test for pre-class questionnaire and post-class questionnaire

No.	*Questionnaire items*	*Mean*	N	SD	t	*Significance (two-tailed)*
Before class						
2.	I have used a PDA before.	3.941	34	1.455		
After class						
24.	I think the one-on-one learning with the PDA is easier to understand than the one-to-many explanations by the teacher.	4.647	34	0.646	−2.534*	0.016
25.	I have learned a lot in this learning activity with the PDAs.	4.588	34	0.557	−2.340*	0.025
26.	Using a PDA to learn lets me feel more liberated.	4.794	34	0.410	−3.510**	0.001

$^*p < 0.05$, $^{**}p < 0.01$.

In addition, paired *t*-tests were administered item by item to investigate the differences between the students' responses to the questionnaire items before and after participating in the u-learning activity; the results are presented in Table 4. According to Table 4, most students had medium prior experience of using PDAs (Item 2), but they selected 'I think the one-on-one learning with PDAs is easier to understand than the teacher conducting one-to-many classes' ($t = -2.534$, $p < 0.05$) (Item 24); moreover, the students felt that 'I have gained a lot from using a PDA to learn' ($t = -2.340$, $p < 0.05$) (Item 25) and 'Learning with a PDA makes me feel more relaxed' ($t = -3.510$, $p < 0.01$) (Item 26). It can be seen that the amount of past experience in using a PDA did not affect the learning motivation of the students.

Comparing this result with other m-learning research mentioned in the previous section, we found that our approach can significantly and effectively increase students' positive learning attitude because of the adoption of the context awareness concept and the implementation of the repertory-grid method as an expert system to guide students' learning, which makes them feel relaxed during the learning experiment. This shows that our technology implementation was smoothly integrated into the curriculum.

Teacher interviews

Concluding from the opinions of the three teachers who participated in this study, a number of differences are identified between traditional teaching and context-aware u-learning (Table 5).

The teachers stated that they used to conduct field teaching with students and explain orally the traits of plants, and sometimes use slides and photos. However, the plants in the photos often looked different from the actual plants because of the shooting angle, seasonal changes and size, which often led to misconceptions. But in mobile and ubiquitous learning environment, students can physically see and touch what they read on

Table 5: Differences between traditional teaching and context-aware u-learning

	Traditional teaching	*Context-aware u-learning*
Instructional style	More passive. Students sit and listen to the teacher.	More active. Students explore the environment and conduct observation activities.
Class management	Large student group. Not easy to pay individual attention.	Personal PDAs. Students can focus on their own learning content at their own pace.
Content presentation	Receptive. Oral explanations with graphics or videos.	Interactive. Multimedia based; question-and-answer support.
Instructional media	Use of PowerPoint, posters, plant pictures and videos for presentation.	Mobile devices, such as PDAs, and authentic life environment.

the textbook or heard from the teachers. Misconceptions can be detected and clarified at the same time, which increases effects on learning.

In addition, class management when taking students outdoors for teaching is often not easy. Only a few of the students would pay attention to the teaching, and group progress is hard to control. When using PDAs, students often focus on their own learning content and conduct their own searches. They are more attended when using PDA than in big groups. Class order is also in command because teachers can now spare more time for monitoring individual progress and giving personal advice instead of having to make a presentation to the whole class in a wide area.

All three teachers held positive attitudes about the PDA-guided learning. They thought that the one-on-one (one PDA per student) approach could adapt to every student's learning progress and condition. With useful and meaningful learning objectives and questions-and-answers, it is possible to increase students' attention and motivation. They also thought that the true effect of PDAs is not to decrease the teaching burden but to increase the effectiveness of the learning process. They said that students like to play the main role in learning, and manipulate the learning process and learning speed on their own. With authentic observation and textual explanation, students have more opportunities to become more active in the process.

The teachers also suggested that the course design could add competition and that the course content should focus on the observation of the detailed traits of plants. If the whole plants are to be observed, affective factors should be included. Activities such as hugging the plant or using adjectives to describe the plants could be added to increase their affective involvement. Therefore, it can also be concluded that although focused observation of detailed traits is quite an appropriate activity to be taught with mobile devices, adding affective activities could make the u-learning more sustainable.

In terms of the system, all three teachers thought that more interactive mechanisms and instant feedback could be added. The learning goals for each stage of learning could be more obvious, and corresponding assessment should be implemented to increase the students' depth of understanding.

In conclusion, from the questionnaire-based survey and interviews described, it is clear that the majority of students desire the teachers' traditional oral explanations to be richer and more in-depth. They also want more learning content to be added into the PDA-based learning. Additionally, the students thought that group learning with cooperative or competitive activities could make the learning more interesting and exciting. With PDAs, learning is no longer isolated, and learning problems can be detected and solved instantly.

Conclusions

Since the technology advancement has enabled learning to happen in places outside of the classroom, education is now possible in our daily lives, not only by teachers but by everyone themselves. Learning materials are no longer limited to textbooks, but are extended to widely accessible content through the Internet.

In this research, we found that the u-learning approach can significantly and effectively increase students' positive learning attitudes. Especially since in this research we adopted context-aware u-learning concepts and implemented the repertory-grid method as an expert system to guide the students' learning, the students felt relaxed in this learning experiment. Moreover, they were able to clearly see all parts of the plants, along with additional information, because of the enhancement of the digital technology. Such real-life observations of real plants can help students make distinctions between plants. Consequently, this research has identified a number of advantages, limitations and possible applications of context-aware u-learning in natural science courses.

First, students can get personal attention from the PDAs, and teachers no longer have to worry about large class management problems. Second, students can more actively learn with their own preferred route and speed, while being the central character in the learning scenario. Third, mobile devices allow students to compare the predesigned learning materials with real live objects. Such an approach increases students' retention and requires them to critically distinguish plant features. Fourth, students can provide their own perspectives instead of having to live with a common viewpoint, a typical relic of traditional classroom-based instruction. Finally, the context-aware u-learning enables the automatic generation of learning materials without the troublesome process of information selection and manual input. This customised learning design with the help of technology is something that is seldom seen in the traditional receptive instructional style.

Additionally, attention to designing context-aware u-learning includes factors such as system stability, content choice, learning activity design, privacy issues, and teacher training. Although system development is an important factor, instructional design and learning evaluation are the most essential components for successful learning.

This research has potential for future application implementation in other subject areas such as the social sciences, humanities, arts and sciences. However, different instructional styles have to be considered according to different teaching situations. In this research, it took about 20 working hours for the teacher and the researchers to prepare the learning content, including the repertory grid and the digital materials. Building another set of trees, or refilling the elements and constructs in the new repertory grid for different subject matter might take different lengths of time, from a couple of hours to a few days, depending on the complexity of content and time needed by the subject matter experts. The application to other situations, environments or schools requires various levels of effort as well. System establishment, digital technology implementation and content design necessitate time and labour to build. The adaptation requires special attention to both system and instructional designs.

Further research is also needed to design more appropriate evaluation methods specifically tailored to context-aware u-learning. It is hoped that this study will prove to be a good reference and a springboard for further research by future researchers.

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Appendix

Table A1: U-learning questionnaire for campus plants learning

Item	Always Strongly agree	Usually Agree	Sometimes Neutral	Seldom Disagree	Never Strongly disagree
Before this learning activity					
1. I was interested in the plants on campus and had actively observed them.					
2. I had used a PDA before.					
3. I had used a digital camera to take photos of plants before.					
4. I had used the Internet to search for materials before.					
5. I had good learning motivation and had searched for supplemental information about the plants introduced by the teacher.					
6. I like the current way of teaching (showing multimedia, such as photos and videos) in this course.					
During the learning activity					
7. I like to observe plants because they look nice.					
8. I like to observe plants because I like nature.					
9. I like to observe plants because plants are helpful to human beings.					
10. I like to observe plants because I can learn more.					
11. I have more interest in plants when using a PDA to observe them than listening to the teacher's introduction.					
12. I attempt to use the PDA to search for related information.					
13. I follow the PDA's guidance to learn additional information.					
14. I think using a PDA to learn is convenient.					
15. I think it is easy to use a PDA to learn.					
16. I am more willing than before to discuss with classmates when observing plants using a PDA.					

Table A1: Continued

	Always	*Usually*	*Sometimes*	*Seldom*	*Never*
Item	*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*
After this learning activity					
17. Being able to use a PDA is one of my greatest gains.					
18. Being able to use a PDA in learning is one of my greatest gains.					
19. I know more about campus plants after this activity.					
20. I pay much more attention to campus plants after this activity.					
21. I would spend more time learning about campus plants after class after this activity.					
22. I like this course because using PDAs to learn is much more interesting than our usual classes.					
23. I am happy to use a PDA to learn about plants.					
24. I think the one-on-one learning with the PDAs is easier to understand than the one-to-many explanations by the teacher.					
25. I have learned a lot in this learning activity with the PDA.					
26. Using a PDA to learn lets me feel more liberated.					
27. Using a PDA to learn can stimulate my learning motivation.					
28. I would recommend the PDA learning system to other friends.					
Reasons why I like to use a PDA to learn.					
Reasons why I dislike using a PDA to learn.					