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Effectiveness of a Mobile Plant Learning System in a science curriculum in Taiwanese elementary education

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A B S T R A C T

This study developed a Mobile Plant Learning System (MPLS) that provides instructors with the ways and means to facilitate student learning in an elementary-school-level botany course. The MPLS represented in this study was implemented to address problems that arise with the use of a didactic approach to teaching and learning botany, as is typically used in elementary schools in Taiwan. To extend opportunities for learning beyond the classroom, this study used personal digital assistants (PDAs) equipped with the MPLS, which provided both teachers and students access to plant information while in the field. A quasi-experimental research design was used to investigate the effectiveness of using the MPLS to support student learning. The responses to questionnaires and interviews indicate that students valued the outdoor learning activities made possible by use of the PDA and its functions. Pre- and post-test results demonstrated that students also benefitted academically from the use of the MPLS and the PDA.

1. Introduction

Thanks to advances in wireless and mobile technologies, it is possible to extend the learning environment far beyond classroom walls and school schedules through the use of mobile devices (Liu, 2007). Giving instructors and learners access to mobile learning (M-learning) environments allows them to teach and learn using mobile devices without being restricted to wire-based communication. M-learning as a supplementary teaching technique is a viable way to minimize constraints of time and place in the learning environment (Luvai, 2007; Huang, Jeng, & Huang, 2009; Huang, Lin, & Cheng, 2009). For instance, an instructor can incorporate outdoor learning activities into a botany class in which the students use handheld devices; the instruction process is enriched by the portability and mobility of these devices. Learners can also utilize handheld devices to learn on their own and to assess their knowledge of plants outside of regular school hours. Furthermore, advances in handheld devices have facilitated the use of multimedia in mobile applications, which gives mobile learners access to a wide variety of richly diversified learning resources.

The rapid growth of hardware and software technologies has created many new ways to realize pervasive learning (Cheng, Shengguo, Kansen, Huang, & Aiguo, 2005; Yang, 2006). It has also given rise to a new concept in the area of distance learning: ubiquitous learning (U-learning), which refers to the way in which students can gain knowledge from traditional classroom methods and resources as well as on-demand from the learning system anytime and anywhere (Huang, Huang, & Hsieh, 2008; Markett, Arnedillo, Weber, & Tangney, 2006; Rogers et al., 2005; Virvou & Alepis, 2005). Distance learning and M-learning can enhance traditional educational methodologies with greater portability and flexibility, the old and the new complementing each other for the benefit of students via U-learning services (Chang & Sheu, 2002). Generally, U-learning and M-learning have some similarities, such as accessibility, immediacy, interactivity, permanency, and the situation of instructional activities (Ogata & Yano, 2004). The biggest difference between U-learning and M-learning is "context awareness." Specifically, U-learning focuses on offering context awareness to each learner to enable them to immerse themselves within a pervasive learning situation.

In Taiwanese elementary schools, the study of plants is a required part of the science curriculum, but many students do not acquire a practical familiarity with plants even though they have taken a botany course in school. This may be because the traditional approach towards the study of plants is restricted to print-based textbooks and other scattered resources that may be used to supplement instructors' in-class lectures. Moreover, there are many varieties of plants, and a number of plants are similar to each other, so pupils often have a limited ability to identify plants.

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Many psychologists, learning specialists and educators agree that practice is one of the most significant ways to enhance instructional outcomes and facilitate students' learning (Gagne, 1985; Gagne, Briggs, & Wager, 1992). However, in Taiwan, since the study of plants is confined to the classroom, students lack opportunities to apply classroom knowledge and thereby acquire the depth of understanding that can only be gained by observation and practice in the outdoors. To resolve the limitations of the didactic approach, the coordinated use of advanced technologies and outdoor learning is a viable means to facilitate teaching and learning about plants in a more flexible, socially engaging and interactive way.

Several pedagogical principles and theories have been expounded on and espoused by the literature with regards to teaching and learning science using a mobile learning paradigm. Cortez et al. (2004) proposed a mobile collaborative learning activity for a science curriculum for high schools in Chile. The purpose of the science curriculum is to introduce each scientific concept with the performance of experiments and observation of phenomena. Yet in reality, students cannot always engage in learning activities actively, which may make it difficult for instructors to maintain the interest and motivation of the class. Aware of this problem, the authors adopted handheld devices as learning instruments and a collaborative learning pedagogy to implement constructivist principles in the science curriculum. The investigation ascertained that the learning environment can facilitate a classroom dynamic that allows students the necessary mobility to work collaboratively. Moreover, students and teachers can make a strong social impact outside the classroom through using handheld devices.

Chen, Kao, and Sheu (2003) conducted an outdoor mobile learning activity for a bird-watching lesson using scaffolding pedagogy in Taiwanese elementary school. The bird-watching activity usually takes place outdoors and allows students a chance to obtain clear and close-up views of birds through a high-quality telescope. However, not every pupil necessarily has the opportunity to make an observation through the telescope because the bird being studied might fly away while students are still standing in a line. Therefore, the authors posited that such outdoor educational activities might benefit greatly from the use of handheld devices and wireless technology. Based on this conjecture, the authors adopted handheld devices as a learning instrument and a scaffolding pedagogy to conduct a bird-watching activity outdoors. The research results indicated that scaffolding pedagogy was suitable for the bird-watching activity, and pupils' learning benefitted from the mobile learning devices.

As mentioned above, the common purpose of these studies was to apply mobile devices with appropriate pedagogy to enhance the interaction between human and human as well as human and environment. With this in mind, this work aims to synthesize learning and IT technology in order to establish a new outdoor-ecological M-learning system named the Mobile Plant Learning System (MPLS) for plant study. Through outdoor learning with the MPLS, students can gain knowledge of plants by interacting with peers and the environment. Moreover, each learner has a convenient way to share personal learning experiences with peers and teachers. To accomplish seamless and context aware learning outdoors, the proposed system can be a stand-alone application when lacking network service that provides information about a plant according to the position of each user.

The rest of the paper is organized as follows: Section 2 gives reviews of the theoretical foundations of this study. Section 3 describes the various functions embedded in MPLS. Section 4 presents the research methodology used in this study, including the research settings and research instruments. A description of the experiment and our analysis of it are found in Section 5. The experiment studies the effects of using handheld devices by comparing two groups of students, one of which used handheld devices to support learning while the other did not. Finally, some notable findings and concluding remarks are made in Section 6.

2. Theoretical foundations underpinning this research

As far as we are aware, electronic tools designed specifically to help teachers create an outdoor component to a botany curriculum and to be used by students in the field are not yet available commercially. This study developed the MPLS and a teaching plan to fill that void. Some theoretical perspectives that indicate why this study would be beneficial and conducive to learning about plants are briefly described with regards to their social, knowledge, and technical aspects.

2.1. Social context

Outdoor learning was adopted as an educational methodology in this research. Not only can it provide students with first-hand learning experiences, but it also provides them with many opportunities to interact with their peers and environment (Garton, Haythornthwaite, & Wellman, 1997; Orion, Hofstein, Tamir, & Giddings, 1997). Previous research indicates that outdoor learning is an active interaction process between learners and their environment (Fåhræus, 2004; Wilde, Harris, Rogers, & Randell, 2003). This research indicates that learners engaging in outdoor learning go far beyond passive acquisition of information from an instructor. Field experiences also help them become more connected to a social network based on friendship, cooperation, and information exchange in a context that reinforces sound academic fundamentals.

This study thus also adopted the PDA as a learning instrument to enhance social context. This kind of handheld device has connectivity capabilities (Infrared, Bluetooth, and WiFi) that easily connect each user. A required component of outdoor learning environments is frequent movement between each activity location, which may make instructors and learners feel separate from each other. Instructors can use the handheld devices to facilitate the connection of learners to a social network and to encourage them to become involved in group discussions. Learners can use handheld devices to share information with peers during group discussions and learning activities (Lai & Wu, 2006).

2.2. Knowledge context

From the viewpoint of the social construction of knowledge, Piaget argues that interaction among peers can lead students to encounter disequilibration, knowledge inconsistency, opposability of perception and ideas, and inadequacy of logical reasoning and strategies; these encounters may then enable learners to develop higher-quality comprehension (Piaget, 1926; Slavin, 1992). Moreover, Vygotsky posits that the construction of knowledge in a community occurs via the social interactions of its peers (Vygotsky, 1978). In other words, each student provides opportunities and resources for his or her classmates to discuss and construct knowledge collaboratively. This situation occurs frequently in outdoor learning, because participants are more likely to have occasions to help each other, share knowledge and resources, foster social interaction skills, direct their learning process, and take responsibility for their peers accomplishing each activity, all in the absence of the type of direct supervision and direction that is typical in classroom settings (Falk, Martin, & Balling, 1978).

Knowledge construction is not confined to an individual; rather it is a social process between individuals, groups and organizations. When engaging in the task of sharing individual knowledge or information at the end of learning, students need to translate information (encoding) and recall the information when appropriate (retrieval) (Nonaka & Takeuchi, 1995). During the sharing knowledge process, learners must figure out which information is important and worth sharing, as well as how to share it effectively. To accomplish the encoding and retrieving tasks, students have to engage in some sort of information-processing activity, such as rehearsal, organization, or elaboration, so as to clarify relationships among pieces of information and compare newly acquired information to previous personal cognition (Gagne, 1985; Gagne et al., 1992; Reigeluth, 1983; Wittrock, 1979).

Bearing this in mind, a series of learning activities geared towards integrating the above tasks into a composite teaching plan was developed. Through participating in these learning activities, learners can share and exchange ideas and information with peers. In order to engage learners in some sort of information processing, a knowledge-sharing function was developed and embedded in the MPLS.

2.3. Technical context

Technologies are indispensable to building E-learning, M-learning, and U-learning environments and they are usually utilized to overcome the barriers of time or space between knowledge providers and to improve access to the knowledge. More practically, technical media are often used to facilitate learners' personal or collaborative learning activities or to assist instructors or learning services providers in performing relative tasks. Through technologies, students can engage in the exchange of knowledge or information without the traditional requirement of the learning community being in the same place at the same time (Hendriks, 1999).

Technical context refers to different technical factors that may influence teaching and learning (Zheng & Yano, 2007). From the view of teaching, different characteristics and functions of technology can prompt instructors to design different teaching plans. Moreover, instructors' preferences and skills in using technology are dissimilar, which may bring about different teaching performance and atmospheres. Similarly, from the view of learning, various learners' preferences and skills in different technologies may bring about different learning attitudes, atmospheres, and performance. The technical context should eliminate or reduce possible technical barriers for instructors and learners, and as such, it is necessary to use the appropriate technology for teaching and learning.

This study employed PDAs with the MPLS as a learning instrument to help students acquire and share personal knowledge of plants quickly and easily. Use of these technologies can improve students' social interactions by providing opportunities to observe and absorb peers' perceptions and reflections. At the conclusion of learning activities, these technologies can also assist instructors and students in aggregation, collation and evaluation of what each participant has learned. Moreover, the PDA has the advantage a small size and light weight, which makes it easy to carry throughout outdoor learning activities. In order to eliminate or reduce possible technical barriers during the outdoor learning, we ask learners to become familiar with the MPLS before participating in outdoor learning activities. The MPLS provides different recording tools and functions to learners, who can adopt ways to document their understanding of concepts according to their technical preferences and skills.

As mentioned above, we have become aware that the social, knowledge and technical contexts have a complementary connection with regards to how they influence teaching and learning. First, social and knowledge contexts are complementary to each other. An excellent social context can provide a better atmosphere and more opportunities for each learner to discuss and construct knowledge with his or her peers. Such communication and interaction can stimulate learners to engage in information-processing activities. Second, the technical context can assist the social context in becoming more consolidated. Appropriate technology can facilitate instructors and learners to connect to a strong social network. Third, the technical context can effectively enhance the knowledge context. Different tools and functions can enable each learner to explicate and share their understandings based on their preferences and skills in the use of technology.

3. Overview of the MPLS

This study describes an MPLS, which was designed to improve the development of a plant curriculum, the learning of the plant curriculum by students, and the subsequent sharing of learning outcomes.

Studying plants outdoors was designated as the principal learning activity in this study. Since portability and mobility are indispensable factors for a learning instrument in an outdoor lesson, the instrument for this application had to be lightweight. It also had to feature cross-platform capability so it could be used for enterprise applications, communications and mobile applications. The authors thus chose PDAs for the MPLS to achieve portability and equipped the PDAs with wireless communication technology to accomplish mobility. The MPLS was designed and built for portability and mobility and was based on Microsoft Windows Mobile 5.0 Pocket PC Phone Edition and .NET Compact Framework 2.0. Generally speaking, the MPLS can be used on any portable computer as long as the application can be installed on it. In order to access information about a plant with maximum speed and flexibility, the PDA must have SQL Server Mobile Edition installed, which is part of Microsoft SQL Server 2005 and lets the application become a stand-alone system in environments lacking network service.

As shown in Fig. 1, the MPLS was designed to provide four functions: (1) content synchronization, (2) plant searching, (3) plant navigation, and (4) knowledge sharing.

3.1. Content synchronization

The content synchronization function is designed to provide instructors and learners with a seamless educational environment. In order to accomplish this goal, the application was developed using two databases, one being a local knowledge database and the other a remote knowledge database. The local knowledge database enables the system to be a stand-alone application in that the system can work with the local knowledge database anywhere, even if the site does not have any network service. The remote knowledge database features a built-in web server for synchronization. Users can utilize network service to synchronize their own data from the local knowledge database

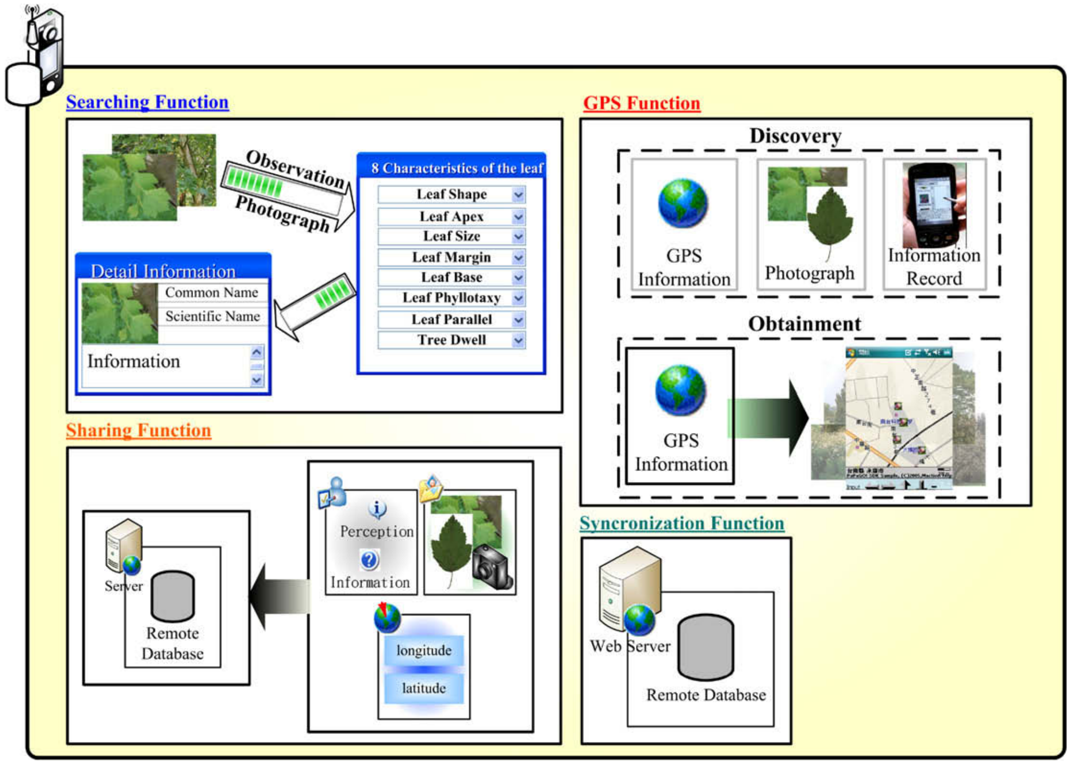

Fig. 1. The system architecture of the MPLS.

with the remote database, because the content synchronization function allows users to conveniently add or modify data about a plant. For instance, in order to ensure that the plant data are as current and correct as possible, instructors can apply this function to update information before beginning instruction, while during the teaching session, instructors and learners can take advantage of seamless instruction because they do not need to worry about external factors, such as network interruptions, that could derail their efforts.

3.2. Plant searching

As shown in Fig. 2, a plant search function offers students the ability to search for information about the plants they are observing. In this study, the authors used leaves as the search objective since many plant leaves have characteristics shapes that can vary significantly plant to plant. Therefore, eight characteristics of leaves were extracted as search criteria (Cheng, Jhou, & Liou, 2007), and to let learners use the function with flexibility, two plant search modes were designed. The two search modes use embedded fuzzy technology, which enables

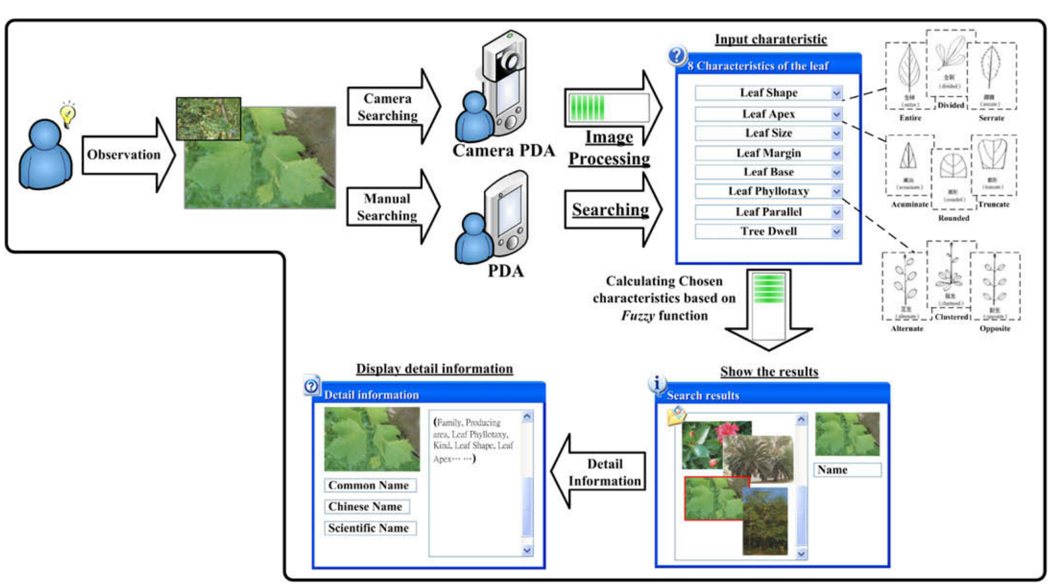

Fig. 2. Flowchart of the plant search function.

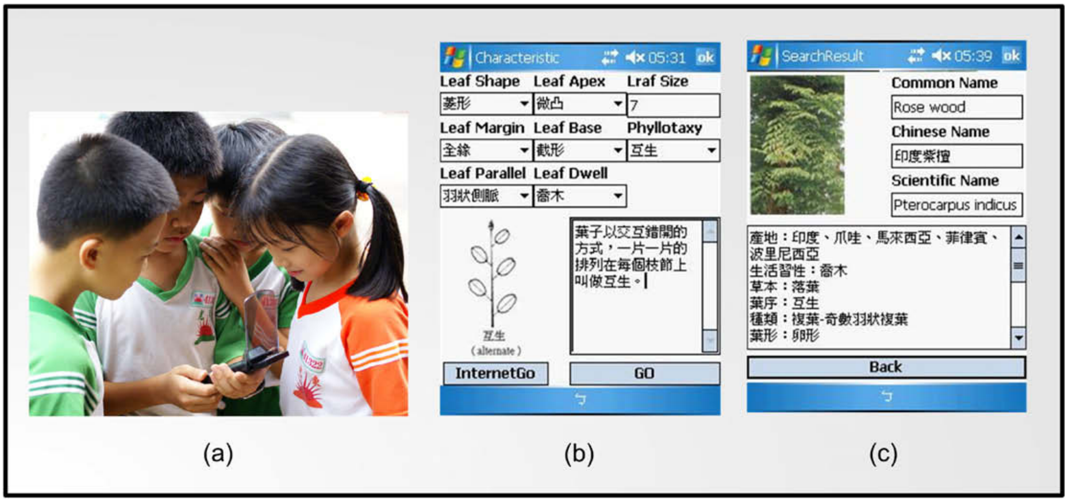

Fig. 3. Process of the plant search.

the system to conduct fuzzy searching. The first mode is a manual search, which provides eight leaf characteristics for learners to choose from. In this mode, the learners do not need to choose all characteristics and may only need to input a minimum of three observed features before the system will perform a fuzzy search according to the selected characteristics (see Fig. 3). In other words, fuzzy searching allows students to search in a situation in which they can not identify all of a plant's characteristics. The second mode is a camera search, which is only supported by devices featuring a camera function. Students can use a camera-equipped PDA to photograph a leaf, and then the system will perform image processing to locate three characteristics of the leaf automatically. After the image processing, students can use the three characteristics or select the remaining properties to carry out a search. No matter which search mode is used, the system will show photographs of the ten plants identified as having the features closest to the selected characteristics on the screen. The learners can click the correct photograph out of the ten plant photographs displayed, and the system will display the plant's detailed information.

3.3. Plant navigation

The design of plant navigation was based on the foundation of U-learning. The MPLS immerses students in a location-aware learning environment through a plant navigation function. This function is only supported on a device with a GPS receiver, which can connect with satellites and compute the longitude, latitude, and Position Dilution of Precision (PDOP) from the satellite's signal. The longitude and latitude indicate the learner's coordinates and the PDOP is the deviation value of longitude and of latitude. After these values are gathered, they are integrated into the course material to provide a broader learning experience for students. As shown in Fig. 4, the plant navigation function consists of discovery and obtainment modes. In the discovery mode, students can record information about a particular plant. For instance, should a learner discover a rare plant somewhere, he or she can use a camera PDA to photograph it, note its characteristics and save the data in the local knowledge database, along with the plant's longitude, latitude, and PDOP. In this way, the local knowledge database grows to incorporate more and more information because the users of the existing database are always adding to it. The second mode is environment sensing. The system applies GPS technology to develop a location-aware environment for students. In this environment, the system can detect the learners' location and identify which plants surround them. The system then displays an electronic map (e-map) to the learners, allowing them to locate and identify known plants in the map area.

3.4. Knowledge sharing

Knowledge sharing is a very popular term within the educational domain, because it has been shown that learners benefit from the sharing of individual learning experiences with other learners (Huang, Chen, Kuo, & Jeng, 2008). Knowledge sharing requires at least two participants, one who offers knowledge and the other who receives it (Hendriks, 1999). Equally obvious is the fact that the first partner must be able to share knowledge clearly, while the second partner must be able to perceive and understand what is being communicated. With this in mind, a knowledge-sharing function was designed to assist each learner in sharing personal learning experiences with others, as shown in Fig. 5. This function allows learners to use photographs and text to record information about a plant, along with any personal notations. When a student completes the record, he can upload the information to the web server via a network service (see Fig. 6). Subsequently, each learner can access others' learning experiences from the MPLS or web pages that include both text records and photographs. Alternatively, students can use each plant's longitude and latitude as previously uploaded to display this information on the e-map and find a plant's physical location. Using this function, students can easily share their experiences, accessing more information than they would have had through individual learning.

4. Methodology

Botany is a mandated part of the science curriculum in Taiwanese elementary schools. The aim of teaching about plants is to ensure that pupils know the name, ecology, function, type, and category of a wide variety of plants. However, in Taiwan, many instructors lack appropriate learning instruments to help pupils fully comprehend and consolidate the contents of the plant curriculum.

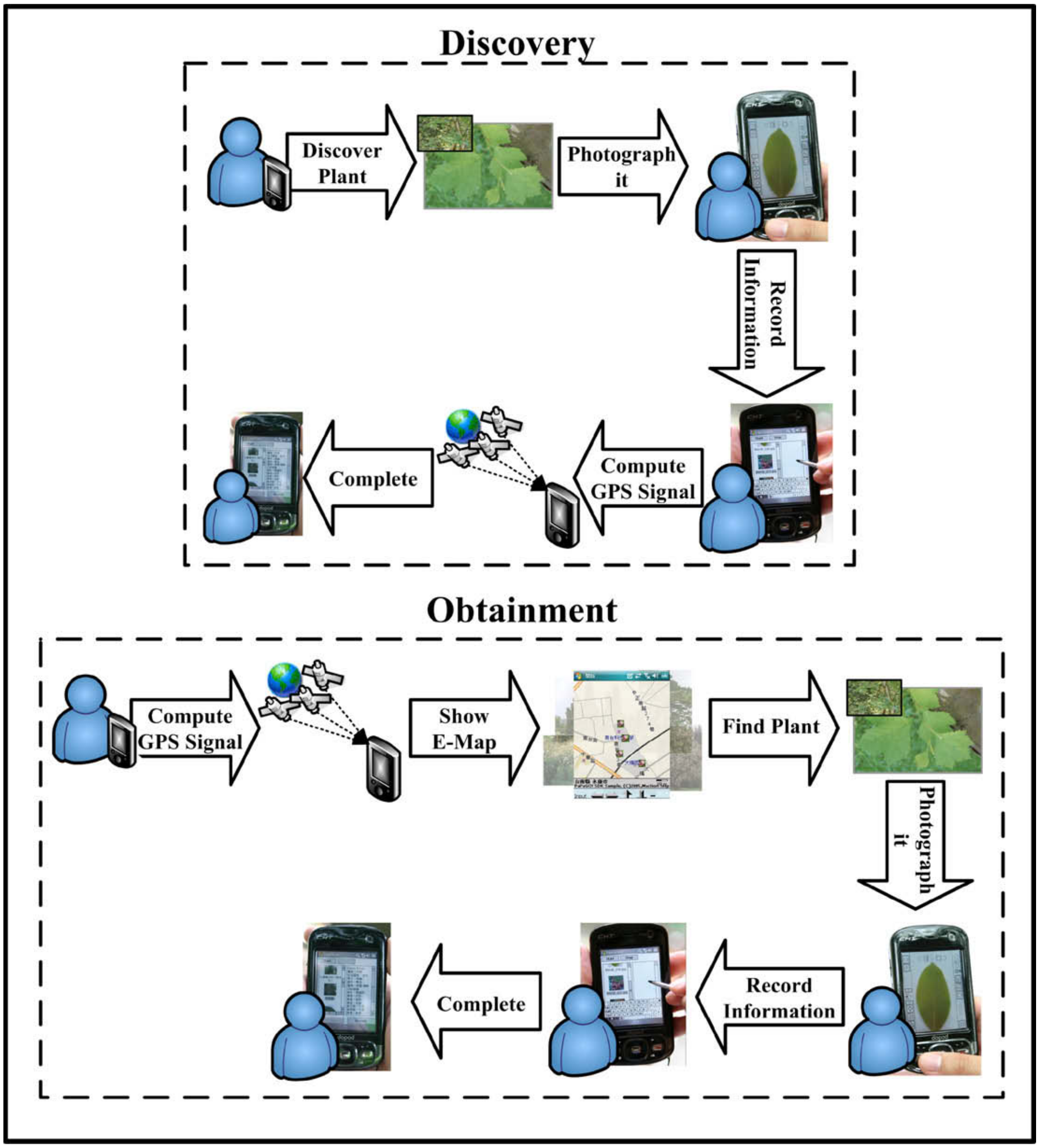

Fig. 4. The two modes of the plant navigation function.

4.1. Research settings

This study aims to provide instructors with the ways and means to facilitate student learning about plants through the MPLS and uses a quasi-experimental research design to investigate its effectiveness. In this study, a treatment group (students using the MPLS) and a control group (students using a guidebook) were organized to investigate both quantitatively and qualitatively the effectiveness of the new tool. The participants in the experiment were a course instructor and 32 students. The average age of the students was 11 years. In the experiment, one group of 16 students served as the experimental (MPLS) group, which had PDAs to use throughout the outdoor learning experience. The other group of 16 students served as the control (guidebook) group and was exposed to similar activities as the experimental group without the aid of PDAs. All participants were asked to take part in the plant course on the Southern Taiwan University (STU) campus.

The instructor coordinated similar learning and teaching activities for the two groups, which included delivering instructions, engaging the learners while they worked with the MPLS or guidebook to complete the activities, stimulating social interaction and discussion between the team members, and consolidating the objectives of the learning activities. In this study, the similar learning and teaching activities of the two outdoor learning experiences were conducted in six stages, which are shown in Table 1. The activities included both observation and practice tasks during 240 min-long periods for both groups. In both modules, learners were divided into four teams to facilitate interaction and discussion (Roberts & McInnerney, 2007). Students were asked to participate in learning activities and to interact with peers and the environment via the MPLS or a guidebook. An analysis of the time distribution of the different learning activities throughout the course showed that the learners spent an average of 50% of the course time working with the MPLS or guidebook for each activity. The students spent the rest of the time interacting with their peers, the environment, and the course instructor. The time distribution shows that the instructor successfully achieved a balance between students' engagement in the outdoor learning activities and interacting appropriately with students to verify that learning took place.

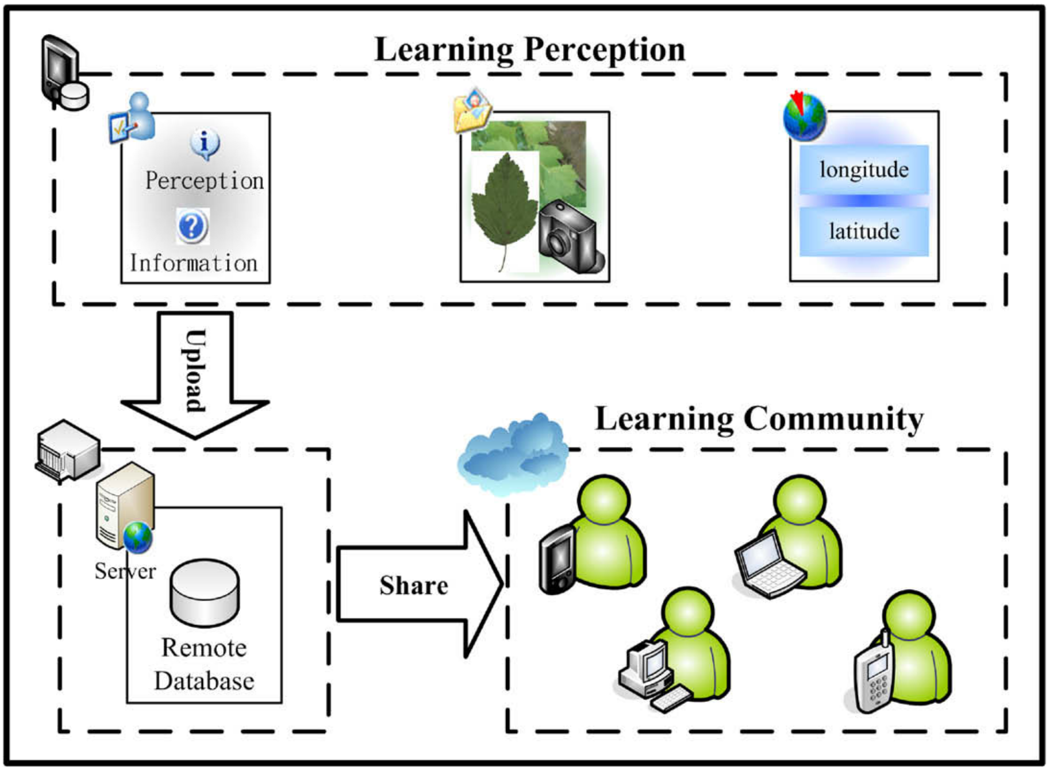

Fig. 5. Diagram of the sharing function.

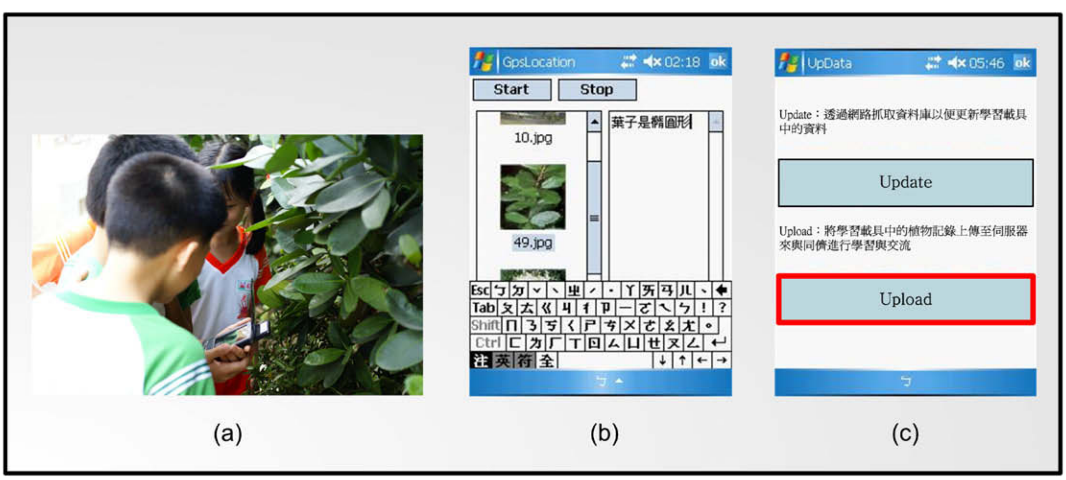

Fig. 6. The process of knowledge sharing.

4.2. Research instruments

Various data sources were utilized to evaluate the students' learning outcomes and attitudes while engaging in the outdoor learning activities, including questionnaires, observation journals, interviews with the course instructor and students, and a pre-test/post-test design.

All students were asked to complete a questionnaire at the end of the post-test after completing all the learning activities. The questionnaire documented their attitudes towards the learning activities. Students in the MPLS group were asked to answer additional questions regarding their perceptions about the use of the MPLS. The course instructor also kept an observation journal in which details of students' interactions were recorded. At the conclusion of the questionnaire, two interviews served to document the attitude of the participants towards the entire learning process, to assess the competence of the experimental group in using the MPLS and to reveal any difficulties the students and instructor encountered during the learning process. Analysis of the data in this study included comparison of the pre-test and post-test results of the two groups. The results of the pre-test were obtained before the outdoor learning activities, and the results of the post-test were gathered after their conclusion. The tests were designed to assess the students' knowledge of the plants under

Table 1
The major learning and teaching activities in the outdoor plant learning process.

Activity name	Activity of MPLS group	Activity of guidebook group	Time
1. The teacher's instruction	The teacher introduced basic concepts and how to use the MPLS in the classroom via a presentation and practice	The teacher introduced basic plant concepts and how to use the guidebook in the classroom via a presentation and practice	50
2. I am a plant detective	Each team observed the characteristics of leaves and attempted to find a particular plant that was assigned by the teacher	Each team observed the characteristics of leaves and attempted to find a particular plant that was assigned by the teacher	30
3. Plant's true colors	Each team was required to find out the name, ecology, function, type, and category of the particular plant using an MPLS	Each team was required to find out the name, ecology, function, type, and category of the particular plant using a guidebook	25
	The instructor asked each team to do an oral report to communicate their new knowledge	The instructor asked each team to do an oral report to communicate their new knowledge	25
4. My favorite	Directed by instructions from the e-map, each team was asked to identify their favorite plant and record their personal experiences and perceptions via the MPLS	Directed by instructions from the teacher, each team was asked to identify their favorite plant and record their personal experiences and perceptions via paper and pen	40
5. A press day	The instructor asked each team to make an informal report about the learning experience and then post it on a website to share with others via the MPLS	The instructor asked each team to make an informal report about the learning experience and then write it up with paper and pen for other students to look at	40
6. Assessment	The instructor used open-ended questions to generate a discussion with students in order to evaluate the students' learning	The instructor used open-ended questions to generate a discussion with students in order to evaluate the students' learning	30

study, including questions about nomenclature, function, and morphological characteristic. The two tests were identical, and the maximum mark that could be obtained in both tests was 20.

5. Results

As mentioned above, students in both the MPLS and the guidebook groups were asked about their perceptions of the outdoor learning activities. Students were asked to fill out a questionnaire by checking responses on a Likert-type 5-point scale. A total of 32 students, 16 students of the MPLS group and 16 students of the guidebook group, completed the questionnaire. A *t-test* was performed on the rating scores to compare students' attitudes between the two groups. The statistical results are presented in Table 2.

Overall, when compared with the students using the guidebook, more students in the MPLS group reported having positive perceptions about the outdoor learning activities (56.25% vs. 31.25%, Table 2, 'SA & A' column). Only 6.25% of the MPLS group said that they disliked outdoor plant learning activities ('D & SD' column), while 25% of the guidebook group indicated that they disliked outdoor plant learning activities. The *t-test* results revealed that there were significant differences in students' attitudes between the two groups. The MPLS group liked outdoor plant learning better (Question 1, $t(30) = 2.403$, $P < 0.05$) and considered the outdoor plant learning activities in the plant learning course helpful (Question 2, $t(30) = 2.179$, $P < 0.05$). However, no significant differences were found between the two groups regarding liking the requirement to deliver an informal report (Question 3, $t(30) = 0.634$, $P = 0.531$), though more students in the MPLS group said that they liked to use informal reports (SA & A, 50% vs. 43.75%) while fewer students disliked it (D & SD, 12.5% vs. 18.75%). In addition, the guidebook group felt that making informal reports was easier when using paper and pen (Question 4, $t(30) = -2.123$, $P < 0.05$). The MPLS group perceived better interactions with their peers (Question 5, $t(30) = 2.15$, $P < 0.05$) than the guidebook group. Of the MPLS group, 62.5% agreed that they had good interactions with their peers (Question 5, SA & A), and almost no students disagreed (D & SD). The questionnaire results also show that the MPLS group indicated that they had better interactions with the environment (Question 6, $t(30) = 3.303$, $P < 0.05$) than the guidebook group indicated that they had.

We also asked the MPLS group to give their perceptions of using the MPLS in Questions 7–13 (see Table 3). Of the students, 75% agreed that the user interface of the MPLS was clear and straightforward (Question 7), and approximately 56.25% thought that the MPLS was easy to use (Question 8). A majority of students agreed that the MPLS facilitated team discussions (Question 9) and increased interactions with other students, the instructor, and the environment (Question 10). Moreover, 43.75% students felt that the MPLS was convenient for sharing learning experiences (Question 11). However, about half of the students said they encountered technical problems in using the MPLS (Question 12). Finally, one third of the students claimed they enjoyed using the MPLS as a plant learning tool (Question 13).

Table 2
Students' attitudes towards outdoor plant learning.

#	Question	Group	SA & A (%)	Neutral (%)	D & SD (%)	Mean	t
1	I like outdoor plant learning	MPLS	56.25	37.5	6.25	3.8125	2.403*
		Guidebook	31.25	43.75	25	3.0625	
2	The outdoor plant learning activities are helpful	MPLS	68.75	31.25	0	4	2.179*
		Guidebook	43.75	43.75	12.5	3.375	
3	I like to use informal reports in plant learning	MPLS	50	37.5	12.5	3.5625	0.634
		Guidebook	43.75	37.5	18.75	3.3125	
4	Making informal reports is very easy	MPLS	25	50	25	2.75	−2.123*
		Guidebook	43.75	37.5	18.75	3.625	
5	I had good interactions with other participants	MPLS	62.5	0.25	12.5	4	2.15*
		Guidebook	50	31.25	18.75	3.125	
6	I had good interactions with the environment	MPLS	68.75	31.25	0	4	3.303*
		Guidebook	31.25	43.75	25	3	

Note. SA: strongly agree; A: agree; D: disagree; SD: strongly disagree.
* $P < 0.05$.

Table 3
The MPLS group's perceptions on using MPLS.

#	Question	SA & A (%)	Neutral (%)	D & SD (%)	Mean
7	The user interface of the MPLS is clear and straightforward	75	18.75	6.25	3.9375
8	The MPLS is easy to use	56.25	25	18.75	3.4375
9	The MPLS facilitates team discussion	68.75	31.25	0	3.875
10	The MPLS increased my interaction with others (students, instructor, and environment)	62.5	25	12.5	3.4375
11	The MPLS is convenient for sharing learning experiences	43.75	31.25	25	3.0625
12	I encountered technical problems while using the MPLS	56.25	31.25	12.5	3.75
13	I enjoyed using the MPLS as a plant learning tool	31.25	31.25	37.5	2.875

Note. SA: strongly agree; A: agree; D: disagree; SD: strongly disagree.

Next, we interviewed the students to capture their perceptions and impressions, and the teacher was interviewed to get her reactions to the experiment. Then, the students of both groups were interviewed to get their feedback on the outdoor learning activities. In all the interviews, the teacher's and students' responses were recorded, and using the audio transcripts, we first summarized the responses of the course instructor and students to question 1–6, as shown in Table 2. After reading the observation journals, the course instructor thought that the students in both groups had rich outdoor learning experiences. However, her observations showed that students in the MPLS group were more engaged and more highly motivated during the learning activities, because the PDA and the MPLS were very appealing to them. It was her impression that the students of the MPLS group demonstrated much more enthusiasm for each learning activity using the PDA and the MPLS than she had ever expected. At the same time, she noted that only a few students from the control group actively participated in the activities, while others were little bit reluctant to get involved. Speed of access to information appeared to influence the behavior of students in each group. Concerning the interactions in the learning activities, the teacher observed that students in the MPLS group often began conversations by using the PDA and manipulating the MPLS with their teammates. In other words, the PDA and the MPLS served as an "ice-breaker" to trigger interaction at the beginning of the outdoor activities. During the lessons, they were usually excited to use the PDA and MPLS to do research and communicate information with others. On the other hand, the instructor noted that students in the control group had fewer discussions with teammates, and some consulted the guidebook individually.

While some results from the students' questionnaires were similar to results from the course instructor's notes, one major difference was that a minority of students in both the MPLS and the guidebook groups would have preferred more direct instruction from the teacher. Students from both groups indicated that learning about plants through the outdoor activities was interesting for them. However, students in the control group thought that using the guidebook was inconvenient and led to reduced interaction with both the environment and their classmates.

In addition to studying the students' attitudes towards learning about plants outdoors, we further analyzed the audio transcripts to gather the MPLS group's perceptions of using MPLS as well as those of the course instructor (question 7–13 in the Table 3). The teacher and the majority of students indicated that they felt the interface of the MPLS is clear and straightforward and that they understood how to manipulate the MPLS easily. According to the transcripts, the "plant search" function was so easy to use that most students enjoyed working with it, which motivated them to search for additional information about plants. During the learning activities, the students in the experimental group would first talk with their team members and then after coming to a consensus would select the plant's characteristics through the MPLS. Students also liked to use the PDA to photograph various plants and to share their photographs with other teams. Somewhat surprisingly, we found out that the instructor had a different point of view. She did not agree that it was the MPLS that encouraged team learning but rather believed that team learning was improved by the outdoor learning activity itself. She also indicated that, in her opinion, the MPLS would be more suitable for individual learning than team learning because the existing system does not support a cooperation service. This was a significant finding in this research. Although the MPLS does not support a cooperation service, students still thought that they had a good interaction with others. One possible explanation for this discrepancy is that outdoor learning activities encouraged students to learn as a team. Another possible reason is that students were motivated by their use of the PDA and MPLS to engage enthusiastically in the learning activity and share their enthusiasm with others. Additionally, the course instructor and majority of students had the same somewhat negative experience with the use of the input interface of the PDA. They indicated that they had to spend a lot of time keying in plant information or their learning experiences. This problem was more pronounced when students tried to key in Chinese words or sentences. Consequently, many students said that they had reduced motivation to record their learning experiences. Furthermore, many students indicated that they encountered difficulties in using the PDA. When some students applied the camera search mode of the plant search function to analyze the characteristics of the plant, they encountered unexpected system halts of the MPLS when the camera search mode failed to analyze the indicated characteristics. If the students pressed other buttons during the period of the search, it sometimes resulted in unforeseen responses. Several students indicated that they could not share learning experiences to the web server owing to the instability of the wireless network at times, and many students did not know how to turn on the backlight feature. Some of these problems resulted from students' unfamiliarity with the PDA, but some problems were due to the instability of the MPLS and the network service. Because of the technical problems encountered, it was not surprising that only one third of the students enjoyed using the MPLS as a plant learning tool even though they felt that the use of the PDA and MPLS made learning about plants more interesting. However, most students indicated that they would like to use the MPLS to learn more about plants in the future, once technical difficulties have been resolved and they have had adequate opportunity to become more familiar with the PDA.

To further evaluate student learning, tests were administered before and after the outdoor learning activities. The pre-test results reveal that the mean of the MPLS group (10.5) was similar to the guidebook group (10.0625). After preliminary analysis, a *t-test* was used to determine whether the two groups were homogeneous at a selected probability level (alpha 0.05 was selected in the analysis), and the result showed that there was no statistical difference between the MPLS group and the guidebook group ($t(30) = 0.616$, $P < 0.05$).

After completing the outdoor module, the course instructor administered a post-test, the results of which showed that the mean of the MPLS group (14.25) was a little higher than that of the guidebook group (12.375). A paired *t-test* was used to analyze the MPLS group at a selected probability level (alpha 0.05), as shown in Table 4. Table 5 shows the means, standard deviations and paired *t-test* of the pre-test

Table 4
Means, standard deviations, and paired *t-test* of the pre-test and post-test measures of the MPLS group in the evaluation study.

Measure	Pre-test		Post-test		Paired *t-test* $t(15)$
	Mean	Std. dev.	Mean	Std. dev.	
Knowledge of plants	10.5	2.0331	14.25	1.6125	7.438*

Note. $n = 16$ for all measures.
* $P < 0.05$.

Table 5
Means, standard deviations, and paired *t-test* of the pre-test and post-test measures of the guidebook group in the evaluation study.

Measure	Pre-test		Post-test		Paired *t-test* $t(15)$
	Mean	Std. dev.	Mean	Std. dev.	
Knowledge of plants	10.0625	1.9822	12.375	1.5864	7.103*

Note. $n = 16$ for all measures.
* $P < 0.05$.

Table 6
Means, standard deviations, and *t-test* of the post-test measures of the two groups in the evaluation study.

Variable	Post-test		*t-test* $t(30)$
	Mean	Std. dev.	
MPLS group	14.25	1.6125	3.316*
Guidebook group	12.375	1.5864	

Note. $n = 32$ for all measures.
* $P < 0.05$.

and post-test measures of the guidebook group. These results indicate that both teaching strategies could assist students in learning plant knowledge.

In addition, we attempted to further use a *t-test* to examine whether the experimental treatment could really enhance the students' learning performance more than the guidebook group at a selected probability level (alpha 0.05 was selected in the analysis). The analysis results revealed that there was a significant difference in students' post-test achievements between the two groups, as shown in Table 6 ($t(30) = 3.316$, $P < 0.05$).

6. Conclusion and discussion

This research has described a learning tool named the Mobile Plant Learning System (MPLS) that provides instructors with the ways and means to facilitate student learning in an elementary-level science unit on plants. The MPLS was designed and implemented to resolve problems that can result from the use of a strictly didactic approach to teaching and learning about plants, as typically occurs in elementary school in Taiwan. This study also involved the use of PDAs with the MPLS to allow teachers and students to work through the course content outdoors. The MPLS was developed to help learners acquire knowledge about plants through four functions: content synchronization, plant searching, plant navigation, and knowledge sharing. With this level of technological support, science teachers can easily incorporate outdoor learning activities into their repertoire of strategies, with demonstrable benefits to the students.

Questionnaires and interviews were used to record the perceptions of participants in the study, and the results revealed that students appreciated the outdoor plant learning activities and the use of the PDA and its many functions. The pre- and post-tests revealed that student learning was also enhanced through students' use of the PDA. In comparing the MPLS group with the guidebook group, we found that PDA use can stimulate students to engage enthusiastically in assigned learning activities, as well as stimulate social interaction and discussion about the course material. We did note that the students of the MPLS group using PDAs were much noisier and less orderly than the guidebook group. We interpret this to be an indication of student enthusiasm and involvement in the activities. While this level of active engagement could pose problems for some teachers who are unfamiliar with innovative teaching methods, proactive and well-planned teachers would be well able to train students to rapidly transition from an animated group experience to the next set of learning activities.

In our study we also noted some technical difficulties. Previous research indicates that handheld devices have the following common drawbacks (Huang, Kuo, Lin, & Cheng, 2008): (1) the software does not integrate well; (2) the embedded web browser is not powerful enough; (3) the input interface is not user-friendly; (4) the screen size is too small; and (5) the battery life is limited. In this study, the MPLS alleviated three of these drawbacks, with items 3 and 5 requiring further attention. Concerning item 3, both instructor and students indicated that the problem of the user interface would make them a little reluctant to use the relational functions of the MPLS. In response, we have improved the input interface from the preliminary MPLS. As shown in Fig. 7, a list was added to the recording interface of the MPLS showing some default words and sentences to assist students. The default key terms used most frequently by all users were extracted from the database. After making this change in the recording interface of the MPLS, we informally asked the course instructor and students of the MPLS group to sample the function again, and they reported that the MPLS was indeed easier to use.

With regard to limitations of battery life, because the length of the outdoor learning activities was only 4 h, the problem did not arise in this study. Nevertheless, battery life is an important consideration in any activity using electronic devices, and course instructors who use

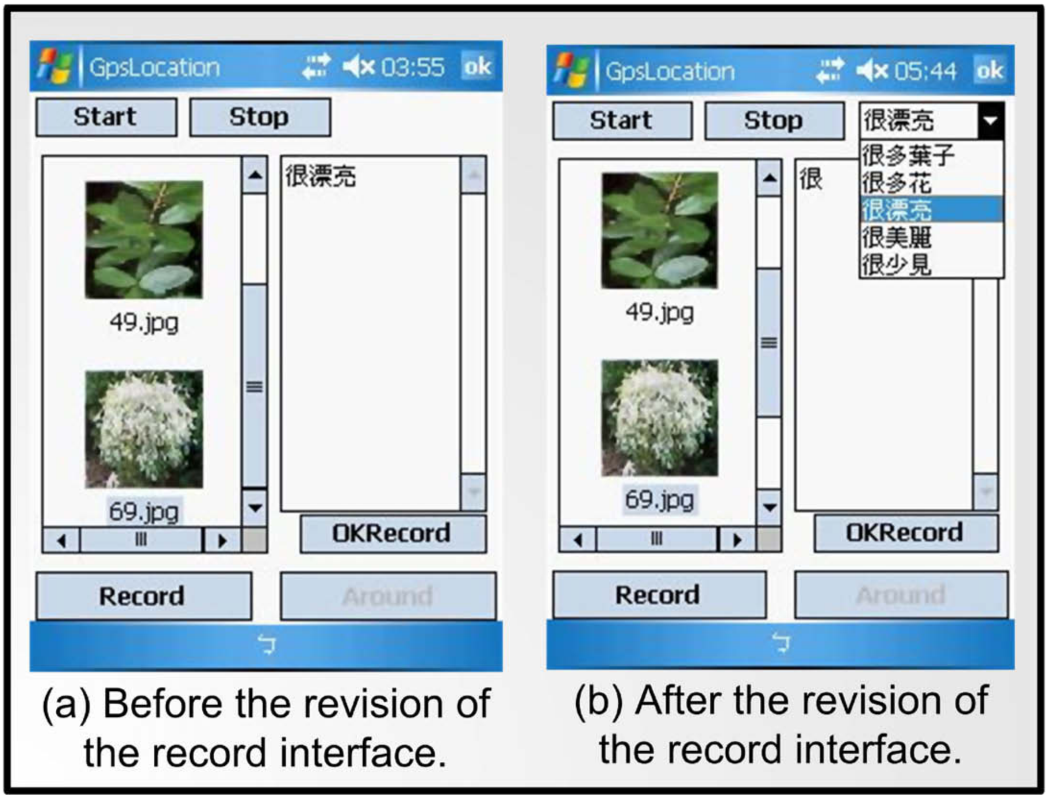

Fig. 7. Screenshots of the recording interface before and after the revision.

the MPLS with PDAs should be aware of the time limits imposed on each session and ensure that batteries are fully charged before beginning an out-of-classroom activity.

In conclusion, these findings give positive, though preliminary evidence that mobile technologies and an outdoor learning strategy are both useful tools in teaching children about plants. The use of handheld devices has many advantages, such as engaging students in learning activities and discussion and facilitating the organization of conceptual information. However, some challenges remain, such as the need to develop a friendlier user interface and to cultivate students' familiarity with the learning instruments before they use them in the field. The future direction of this study is to develop suitable cooperative functions for learning about plants. Moreover, as the knowledge database grows, semantic techniques will be designed and applied to further enhance the knowledge database, which can organize the database for efficient management. As for the limitations of handheld devices, it is likely that these will be readily solved through ongoing, rapid improvements to communication technology. Our next step will be to devise experiments in different subjects and disciplines in a variety of educational contexts. We hope our work will act as a catalyst to encourage teachers to take the steps needed to help their students develop the knowledge, skills and attitudes required for success in our rapidly changing, information-based global society.

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