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# Location Based Services for Outdoor Ecological Learning System: Design and Implementation

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**ABSTRACT**

This paper aimed to demonstrate how location-based services were implemented in ubiquitous outdoor ecological learning system. In an elementary school in northern Taiwan, two fifth grade classes on an ecology project were randomly selected: The experimental group could access the ecological learning system on hand-held devices while the control group was guided by a human guide. Flow Learning was adopted as the teaching scheme for this study. We seek to arouse students' motivation to study first, have them focus next, create opportunities for acquiring knowledge by directly observing the phenomenon to be studied, and finally encourage students to share what they have learned. The results showed that the experimental group outperformed the control group on the ecological knowledge test. Furthermore, the students in the experimental group felt satisfied with the ecological learning system supported by positioning systems. The pedagogical implication of this study is that students need direct experience to gain an understanding of a certain topic.

**Keywords**

Ubiquitous learning, Ecological learning, Location-based services

## Introduction

Since its inception, ubiquitous computing has benefited its users by enabling them to interact with context-sensitive materials. As this technology matures by offering outstanding and unlimited computer-based services, ubiquitous computing has gained a wide popularity in education and ubiquitous learning (u-Learning) has become its most important application (Hwang, Tsai, & Yang, 2008). One advantage of u-Learning is its potential for digital learning experiences, i.e. immersive learning experiences gained via digital technology, which help users reflect upon what they have learned from their environment. Such experiences are contextually sensitive, relevant to where users are at the time of learning, digitally mediated and affectively compelling. Learners, when engaged in u-Learning, expect immediate feedback from the learning systems so as to meet their needs of learning (Chang, Sheu, & Chan, 2003). In trying to meet learners' needs of immediate feedback, the technology of context awareness comes into play (Dey, 2001; Yang, Huang, Chen, Tseng, & Shen, 2006). With the help of this technology, learners are able to access learning materials that are relevant to the learning environment, which in turn improves the overall learning results.

Currently, the location-based scheme is the most frequently used model of u-Learning. The central feature of this location-based model is the positioning technology, which not only provides learners with relevant materials for learning (Chan, Sheu, & Chan, 2003) but helps them focus on their studies (Feng, 2007). The positioning technology used in a u-Learning environment comes in two forms. The technology involved in the outdoor experience includes electrical coordinates (Jacobson, 2007), Global System for Mobile (GSM) communications (Sun, Liu, & Xie, 2003), and Global Positioning System (GPS); the technology involved in the indoor experience incorporates Access Point (AP), Radio Frequency Identification (RFID), Infrared (IR; Hazas, Scott, & Krumm, 2004), Quadratic Residue Code (QR-code; Chaisatien & Akahori, 2006). Due to the maturity of this technology and the wide popularity it enjoys, GPS is widely used in outdoor positioning.

Outdoor learning, in general, must help foster a keen power of observation in learners out of their hands-on experiences (Cornell, 1998); successful outdoor learning must have such essential components as experiences in authentic contexts, adaptation to changes, and facilitating both hand and brain. Furthermore, outdoor learning should avoid learning activities targeting one single subject; rather, it should incorporate multiple subjects, fields of knowledge and skills to create an integrated learning environment (Ford, 1981). Ecological education is a typical example of outdoor learning. In traditional outdoor ecological leaning, learners are usually aided by guides, who organize the learning materials, teach and interact with highly motivated learners. For those who have no chances to interact with a guide, the objectives of the outdoor ecological lessons may not be achieved as expected. In a u-Learning environment, however, devices such as PDAs or tablet PCs may improve learners' motivation, boost their sense of responsibility, and encourage them to interact with context-sensitive materials. An active engagement in the learning environment makes learning interesting and therefore boosts students' motivation to explore a topic.

Gay, Reiger, & Bennigton (2002) proposed a plant learning system in a school that included classification and living environment of plants in the learning database. Learners used mobile computers to retrieve the information of plants and to collect the living environment information of plants in the campus. Then, learners could discuss the observation result in the classroom. Chan, Kao, & Sheu (2003) proposed a bird-watching system, which could be accessed in PAD's with the scaffolding theory. Using the system, a teacher could lead students to outdoor for watching birds. The students could use PAD's as the tool to search the bird information from the learning material database and to answer the question from the system. Then, Chen, Kao, Yu, & Sheu (2003) proposed another system, using PAD's with the independent learning theory, for learning butterfly related knowledge outdoor. However, the three aforementioned systems lacked automatic location-based services. Because of that, teachers must lead students to predefined learning locations, which resulted in low self-control levels for the students.

The Ambient Wood project, supported by the Equator Interdisciplinary Research, is combined with multiple technologies for outdoor biology learning (Rogers, Price, Randell, Weal, & Fitzpatrick, 2005). Using the wireless location technology, the system can provide the related biology information for the student users. The students can use the sensors to detect the environment variables for learning lessons related to a particular ecosystem. Lin, Tan, & Chu (2009) proposed an outdoor natural science learning system by using the RFID location services. Both of the two systems provided location-based services; however, the learning environments not only included related learning material but also the additional facilities, such as wireless access points and RFID readers, for positioning services must be pre-installed.

Outdoor learning requires proper guidance, or learners will not learn anything due to a lack of concentration (Eshach, 2007). This study, therefore, adopts Flow Learning as the teaching scheme for the outdoor learning project (Cornell, 1998). Flow Learning is learner-centered and can be applied in teaching any subject matter with proper adjustments. Its goal is to arouse interest in the tasks in students, to increase their sensitivity to the environment, and to have them experience a natural environment and develop self-awareness with joy. The four stages in Flow Learning are as follows:

- Awaken Enthusiasm–This stage emphasizes how learner's attention can be focused on the lesson or experience once their enthusiasm is awakened. Without enthusiasm, learners cannot learn much from the tasks.
- Focus Attention–At the end of the first stage, learners need to try to calm down and focus so that they can learn more from the environment.
- Direct Experience–The stage is set to have learners interact directly with the nature to gain more knowledge of it.
- Share Inspiration–In the final stage, learners are asked to reflect on what they have learned so that they can develop positive beliefs and share their learning experience.

In this study, we proposed an ecological learning system incorporating the Flow Learning method for a u-Learning environment and sought to investigate whether learning in such a system has a better result.

## Method

### Subjects

The subjects of this study were two fifth grade classes in an elementary school in Bali, Taipei County, Taiwan. One class of 32 students was randomly chosen as the experimental group and the other of 30 students as the control group. Both groups were assigned to study identical materials on the Mangrove Conservation Area in Bali, Taipei County, Taiwan. The area was divided into four zones, including the Mangrove swamp, waterfowl, crabs and mudskippers zone. Both groups were asked to complete the task designed in the learning sheets for each learning zone.

## Procedure

In the beginning of the experiment, the two groups were asked to take the pretest on ecological conservation. After the pretest, both groups took outdoor ecology classes in the same place for four hours. The control group was instructed by an experienced guide while the experimental group experienced u-Learning with handheld mobile devices with an active positioning system locating their learning context. The handheld mobile device used in the study was ASUS P535 PDA, with GPS and wireless available.

The learning activities designed for the two groups were the same. The control group used traditional outdoor teaching method. The learning materials and learning sheet of the control group were printed in paper. A guide led the control group to visit the learning areas one after another. When the control group arrived at a predefined learning location, the guide introduced related ecological knowledge to the students. Then, the students could refer to the learning materials and finish the task described in the learning sheet.

How u-Learning took place in the experimental group is described below. When the learning system detected changes in the learners' locations, it connected to the learning location database through the positioning service system, located where learners were, and transmitted the information of learners' location to the outdoor ecological learning system. The learning system then searched for such relevant teaching materials as introductory texts, video clips, and photos in the outdoor ecological learning database, and presented them upon request on the PDA.

After locating where learners were, the learning system showed a map of the target zone and provided learners with multimedia learning materials relevant to the ecological zone. It is so designed to help learners learn the names, characteristics, and habits of the target animals and plants. In addition to studying the prepared materials, learners could interact with the learning context by playing matching games and finishing several tasks: taking photos, writing comments and drawing to realize the goal of learning outside the classroom.

When the treatment was over, both groups took the posttest on ecological conservation. In addition, the experimental group was asked to fill out a questionnaire. Regarding data analysis, this study adopted one-way ANOVA for independent samples to discuss the effects of different teaching methods on students' learning results. The two teaching methods were the independent variable, the scores on the posttest after the lesson was the dependent variable, and the pretest score before the outdoor ecology lesson was covariance. The $\alpha$-level was set at 5%. Both groups were observed in their learning.

## Experimental Tools

### *Ecological learning system*

U-Learning with context awareness activities must be combined with positioning systems to achieve location awareness. With the help of the GPS, outdoor positioning systems can perform a general positioning over the entire area. The information thus obtained is compared with what is in the positioning service database, which offers better options for a u-Learning system. It remains unanswered how to implement the more effective context awareness functions in the u-Learning system. There are no standard methods to construct positioning functions. In this study, a simple and reliable approach is proposed to implementing the positioning function in a u-Learning environment.

Under this framework, there are two databases involved, namely a learning materials database and a positioning service database. It is the latter that provides the location-based context awareness function. The positioning device first identifies the learner's present location. In a u-Learning environment, a set of learning locations is chosen in the beginning and all the relevant information is stored in the positioning service database. Data on a learning location include a serial number and its longitude and latitude. In addition, learning materials for a given location are stored in the learning material database. When a learner with the learning device reaches a chosen learning location, the proposed system can detect his/her arrival via the GPS signals (especially, longitude and latitude) sent to the PDA. The serial number of the location can be found in the positioning service database and is sent to the learning device. The device would then search the learning materials database for the appropriate material whose number corresponds to the serial number, organize and present the materials in learners' learning devices through the wireless network. A framework of a u-Learning system is shown in Figure 1.

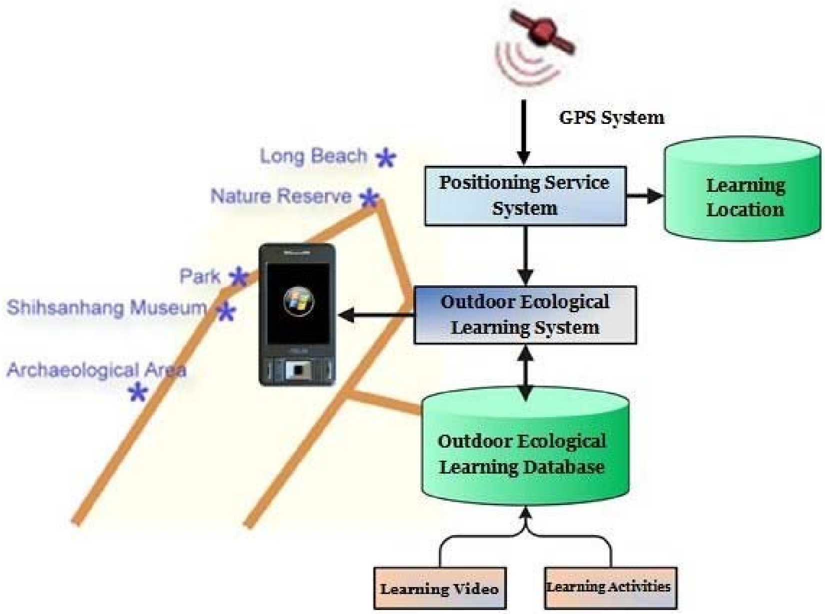


*Figure 1*. A framework for the outdoor ecological learning system

This teaching scheme is organized around related teaching activities. Figure 2 shows how the scheme in question is structured. Under this scheme, each learner enters the reservation area with a PDA, whose built-in GPS can pinpoint the subject's location; acting on the information, the system will present teaching materials related to the location to help learners learn about the ecosystem. The outdoor learning theory of Flow Learning is incorporated into the teaching activities involved in this scheme. The entire process is as follows:

I. The present location: The location where the team member hits the "position" button will be shown on the PDA screen.
II. Tasks and games: Upon knowing the subject's location, the system will identify the present time and season and engage learners in the context awareness learning of the ecosystem. This function is inspired by Flow Learning, the first stage of which seeks to generate interest in learners in the beginning before they move on to the next phase.
III. Area map: Learners now are introduced to the second stage of Flow Learning─focusing. Students learn about local animals and plants by teachers teaching relevant facts about the local ecosystem and by their watching video clips on the ecosystem.
IV. Tasks to be completed: Pressing this icon on the screen, learners will be able to know what they have accomplished and what remains to be done. Also, learners can scan their learning portfolio anytime to achieve post-learning self-evaluation and an exanimation of the learning results.
V. Taking photos and writing comments: Next, learners go straight into the reservation area. Following the instructions on the worksheets provided by the system, teachers assign tasks to individual learners who are then asked to move on to the third stage—experiencing it directly. The scheme suggests learners record what they see by taking photos and writing on the PDA screens; then, students are free to share what they learned as well as their personal experiences with other teams and teachers. At this point, the learners will have reached the fourth stage—sharing reflections.

An emphasis on location-based services and the implementation of Flow Learning are the two features of this scheme. The following is a detailed explanation of the two features.

The location-based related features involved in the study are the GPS positioning system and location related learning activities. In the GPS positioning system, this study uses the PDA mobile device loaded with windows mobile version 6, and develops via the API (Application Program Interface) of GPSID (GPS Intermediate Driver). GPSID is a mediating program that Microsoft provides to windows mobile. From the API stored in GPSID, the system can indirectly obtain the GPS-related information, including longitude, latitude, altitude, speed, positioning satellite information and accuracy. GPSID serves as a transition between the user interface and GPS satellite. The user interface can store various GPS receptors, and could quickly store GPS coordinates without the necessity to write relevant codes. The operation of GPSID is shown in Figure 3 below. The greatest convenience of utilizing GPSID is that developers can simply analyze the GPS Positioning System code (i.e., National Marine Electronics Association, NMEA; Figure 3) to obtain accurate GPS coordinates for the purpose of positioning. The detail computing process is shown in Appendix A.

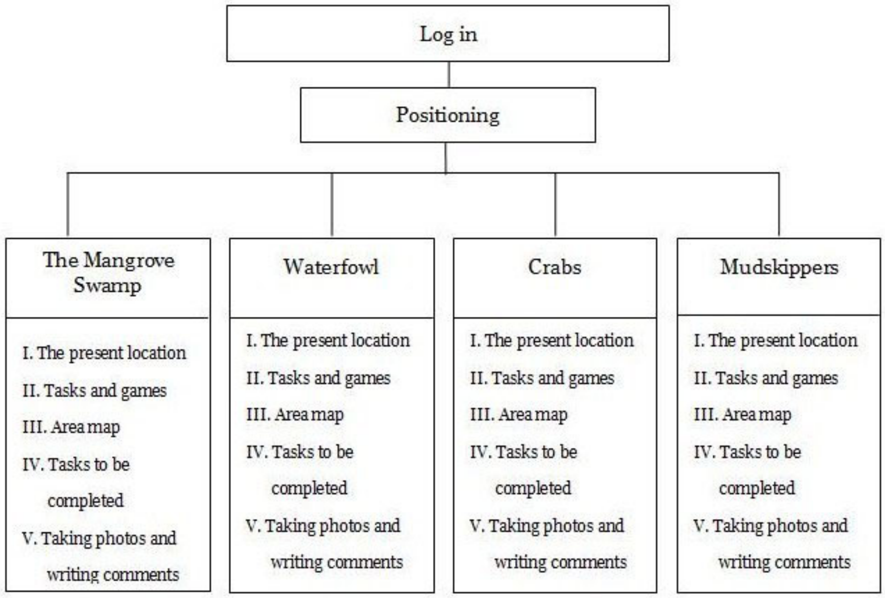

*Figure 2*. System structure diagram

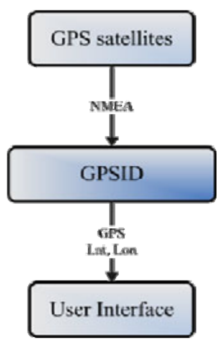

*Figure 3*. The operation of GPSID

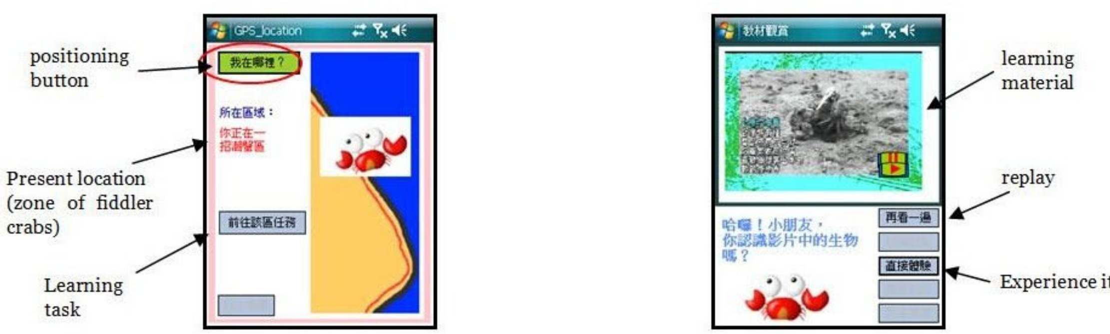

*Figure 4*. Snapshots of the location (left) and learning materials (right)

The central idea underlying the current study is implementing Flow Learning in the teaching process for developing a location-based outdoor ecological learning system. Sample snapshots and explanations of the system are as follows.

- Log into the positioning page : Learners press the “position” button, as shown in Figure 4 (left), to start GPS positioning, and the system will guide learners to the nearest learning sites, as shown in figure 4 (right).
- The First Stage of Flow Learning–Awaken Enthusiasm：This study uses questions and games to draw students’ attention and arouse a keen interest in the ecosystem, as shown in the samples in Figures 5 and 6.


*Figure 5*. Snapshots of a question and a game


*Figure 6*. A Snapshot of three tasks of Fiddler Crabs

(Translation) Boys and girls, after watching the video of fiddler crabs, you are now to finish the following three tasks. First, take a photo of the fiddler crabs or their habitat. Second, write something about the fiddler crabs in your photo. Third, share what you have learned and your reflections in our online forum for this class.

- The Second Stage of Flow Learning—Focus Attention: This stages features educational video clips on ecosystem-related information about native animals and plants, as shown in samples in figures 7 and 8.
- The Third Stage of Flow Learning—Direct Experience: In this stage, worksheets will be handed to learners, who are asked to find the animals and plants living nearby and to take pictures of them. Figures 9 and 10 are the sample pictures taken by the learners.
- The Fourth Stage of Flow Learning—Share Inspiration: In this stage, learners are expected to present what they learned and experienced at a given location with the help of the inbuilt writing pads. Figures 11 and 12 show learners’ reflections written on the PDA screens.

The system is put to the test after its completion. The subjects were a class of fifth graders of Bali Elementary School of Taipei County. A number of professors with degrees in e-Learning along with two senior elementary school teachers assessed the viability of each of the functions. To take evaluation a step further, users were given questionnaires whose results would be the criteria for modification.

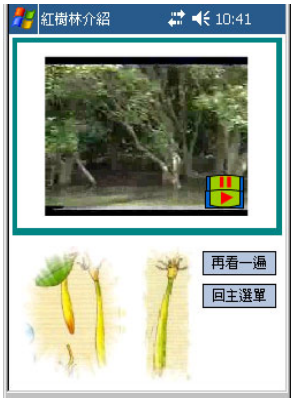


*Figure 7*. Snapshot of the Clips (1)

Facts about the mangrove

Replay

Back to the menu


*Figure 8*. Snapshot of the Clips (2)

Video watching

Crab: Hello, kids! Do you know what the creature on the clip is?

Replay

Experience it

Back to the menu

Figure 9. Snapshot of the photos (1)

Figure 10. Snapshot of the photos (2)


Figure 11. Snapshot of Learners' Reflections (1)

(Scribble) Crabs are so cute.

Figure 12. Snapshot of Learners' Reflections (2)

(Scribble) I'm happy to see water birds.

### Instruments

Two types of instruments are used in the study: tests on ecological conservation and a questionnaire. The tests on ecological conservation are administered before and after the treatment as a pretest and a posttest respectively. The number of test items and the difficulty level are the same but what is covered in the tests differed. Issues covered in the tests include environmental protection, ecological conservation, the relationship between living beings and the environment, the relationship between humans and nature, the conservation and use of resources, and the development and use of energy. The Kuder-Richardson reliability of the tests reaches .68 in a pilot study conducted in another fifth grade class and their validity is checked by an expert on ecological conservation. In the questionnaire of ten items, subjects are asked to rate, on a scale of 1 to 5, how they like the activities in the study with point 5 indicating they are highly satisfied with the activities and point 1 indicating they are not satisfied with the activity. A survey is conducted on user satisfaction with the teaching scheme, teaching activities and materials involved in this study to explore how learners perceive the teaching materials, their level of motivation to learn, how smoothly the system runs and how satisfied learners are with the teaching activities throughout the experiment. The complete questionnaire is shown in Appendix B.

## Results

### Quantitative analysis

This study aims to analyze the learning effect of the u-Learning ecology system. While the control group used traditional guiding learning method, the experimental group used u-Learning system, which provided the location-based services. One-way ANOVA for independent samples was performed to analyze the effects of different teaching methods on students' knowledge about environmental conservation. The scores of the pre-test, post-test and adjusted post-test of both groups are shown in Table 1.

*Table 1*. The descriptive statistics of the study

| Groups | Pretest | | Posttest | | Adjusted Posttest | |
|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SE |
| Experimental group | 78.78 | 2.65 | 93.50 | 7.22 | 93.30 | 1.22 |
| Control group | 77.03 | 4.54 | 83.37 | 7.43 | 83.58 | 1.26 |

Table 2 shows the results of the equality of variances, which confirmed the homogeneity of variances for the two groups. Additionally, the test results ($p$=0.65>0.05) of between-subject effect, which indicate the assumed homogeneity of regression coefficients for the two groups, were gathered for the remaining test.

*Table 2*. Test for homogeneity of regression coefficients

| Sources of variation | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| Between groups (Treatment) | 160.10 | 1 | 160.10 | 3.54 | .65 |
| Within Groups (Error) | 2622.12 | 58 | 45.21 | | |

Table 3 illustrates the ANOVA result for the study. Since the figures in Table 3 shows a significant difference and the sets of scores reach a significant level of difference ($p$<.05) between the two teaching methods, it is necessary to know which method is better. After eliminating the effect of the pretest scores, the study still found the experimental group obviously outperformed the control group, as shown from the adjusted means of the posttest in Table 1. This statistically significant difference indicated that the u-Learning system proposed by the study was effective in improving the outdoor ecological learning.

*Table 3*. One-way ANOVA of the tests

| Sources of variation | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| Between groups (Treatment) | 1451.7 | 1 | 1451.7 | 30.7* | .000 |
| Within Groups (Error) | 2782.2 | 59 | 47.1 | | |

*$p$<0.05

In addition, the mean score of the questionnaire was 4.51, indicating that participants in the experimental group enjoyed the outdoor ecological learning activities. The detailed results of each item in the questionnaire were shown in Table 4. We note that the highest score is item no. 10 (4.78), "*Generally speaking, I am happy with the outdoor ecology learning*." It means that the learners of the experimental group were really satisfied with the learning method proposed by the study. From scores of the items no. 1, 4 and 8, i.e., 4.63, 4.59 and 4.56, we found that the learners enjoyed the whole learning process as they used the PDA combined with the Flow learning method. On the other hand, the lowest score is item 5 (4.1), "*I am satisfied with the stability of the learning system used in the task*." It represented that the proposed system should be improved to be more stable. Since the proposed system used GPS technology, the communication was influenced by many factors, such as weather, location, and the remaining power of the PDA. Discussion on how to reduce the complexity of the system will be presented in the Conclusion section.

*Table 4*. The descriptive statistics of the questionnaire

| | SA | | A | | N | | D | | SD | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | N | % | N | % | N | % | N | % | N | % | M |
| 1 | 23 | 71.88 | 7 | 21.88 | 1 | 3.13 | 1 | 3.13 | 0 | 0.00 | 4.63 |
| 2 | 21 | 65.63 | 6 | 18.75 | 4 | 12.50 | 1 | 3.13 | 0 | 0.00 | 4.47 |
| 3 | 21 | 65.63 | 6 | 18.75 | 4 | 12.50 | 0 | 0.00 | 1 | 3.13 | 4.44 |
| 4 | 21 | 65.63 | 9 | 28.13 | 2 | 6.25 | 0 | 0.00 | 0 | 0.00 | 4.59 |
| 5 | 19 | 65.52 | 6 | 20.69 | 4 | 13.79 | 0 | 0.00 | 0 | 0.00 | 4.10 |
| 6 | 16 | 50.00 | 5 | 15.63 | 10 | 31.25 | 1 | 3.13 | 0 | 0.00 | 4.53 |
| 7 | 19 | 59.38 | 9 | 28.13 | 4 | 12.50 | 0 | 0.00 | 0 | 0.00 | 4.47 |
| 8 | 22 | 68.75 | 6 | 18.75 | 4 | 12.50 | 0 | 0.00 | 0 | 0.00 | 4.56 |
| 9 | 22 | 68.75 | 7 | 21.88 | 1 | 3.13 | 0 | 0.00 | 2 | 6.25 | 4.47 |
| 10 | 26 | 81.25 | 5 | 15.63 | 1 | 3.13 | 0 | 0.00 | 0 | 0.00 | 4.78 |

Note: N=32; SA=Strongly Agree, A=Agree, N=Neutral, D=Disagree, SD=Strongly Disagree

The results in Tables 1 and 3 confirm that the experimental group, who engaged in u-Learning with positioning systems, outperformed the control group, who learned in a traditional manner from the guide. According to past literature, it is speculated that u-Learning supported by location-based services significantly surpass traditional learning from tour guides because the former facilitates interaction with the learning environment and provides learners with the learning materials and activities that are most relevant to the immediate learning context. In contrast to the traditional outdoor ecology learning, in which learners might not listen attentively while the guide is giving instructions, mobile outdoor ecology learning enables learners to interact with the immediate context and keep track of their own progress all along.

Moreover, results from the questionnaire show that learners enjoy learning on mobile devices. Therefore, the findings of this study not only confirm the need for the positioning technology to be incorporated into u-Learning but also come as uplifting news to the u-Learning researchers.

**Qualitative analysis**

In order to verify the collected quantitative data and to prove the usefulness of Flow Learning, we used four cameras at each learning zone to record the learning processes for both groups. Moreover, the proposed system can log the writing and photo actions by the experimental group for observing the learning behaviors of the learners.

From the video record observation, we noted that the majority number of students in the control group focused on learning about only five to ten minutes at each learning zone. This result is similar to the outcome of Eshach's (2007) study, in which most learners were unable to concentrate their mind on the learning task in informal learning environment.

As for the experimental group, the group used PDA integrated with the Flow Learning method. Therefore, we observed the student's behaviors of the experimental group in each stage of the Flow Learning. In the Awaken Enthusiasm stage, games and questions were implemented to attract the student's attention. Most of the students were immersed in the game playing. During the play, the students can help each other and learn the knowledge embedded in the game. All of the students can finish the tasks provided by the system in the first stage. Figure 13 illustrated how students were immersed in the game.

*Figure 13*. The example of awaken enthusiasm stage

In the second stage, Focus Attention, learners need to calm down and focus so they can learn more from the environment. After the game playing in the first stage, the proposed system provided learners with the ecosystem-related video via PDA. When the learners are watching the video, they can observe the plants and animals immediately. As shown in Figure 14, the proposed system supplies opportunities of interacting with nature to the learners.

*Figure 14*. Illustration of focus attention

The next stage is Direct Experience. This stage is set to have learners interact directly with the nature. The learners in this stage were asked to find the animals and plants and to take photos of them. During the search, the learners can collaborate with another. All students felt that the tasks were amusing. Figure 15 shows the illustrations of Direct Experience stage.

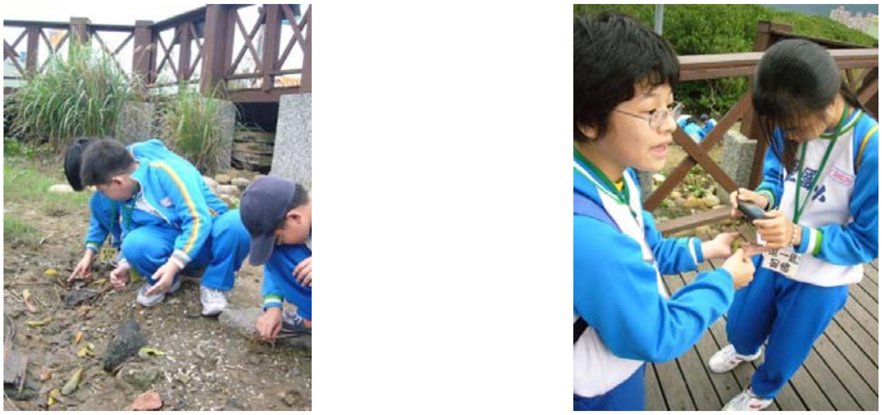

*Figure 15*. The examples of direct experience stage

In the final stage, namely Share Inspiration, learners were asked to reflect on what they have learned. All learners wrote down their experiences in the PDA via the hand-write function. The major parts of the writing contents were that the learning method was funny and that a lot of ecological knowledge could be learned.

Compared with the control group, the experimental group can focus more on the learning activities. As the above quantitative and qualitative data analyses have demonstrated, the proposed system does assist learners in their outdoor ecology learning.

## Conclusions

This study proposed a u-Learning system for outdoor ecology learning. The proposed system used GPS to offer location-based service to support students learning about the right time and right place. When a student approaches a predefined learning zone, the proposed system can automatically present the learning materials and activities, related to the learning zone, to the students. Flow Learning method was adopted to lead the outdoor learning activities.

As shown in test results and related observations, the experimental group performed significantly better than the control group. Although the study does not emphasize collaboration learning, the students of the experimental group helped each other actively in the whole learning process. With the assistance of the positioning technology, learners can not only learn from unknown materials by themselves but also enjoy u-Learning in a real-life context. Moreover, teachers can use multimedia devices and applications as they design courses and activities. Therefore, u-Learning supported by the positioning technology is not just learning from portable digital learning materials or illustrated materials that are not engaging without the potential for enabling learners to interact with the environment. Instead, it can better meet the needs of learners and teachers alike, helping the latter in designing lessons for outdoor or on-campus learning.

One pedagogical implication of this study is that since learners in the present study expressed great enthusiasm about Flow Learning, teachers may give students more opportunities to learn by seeing, watching, touching and experiencing. Limitations of the current study and recommendations for future studies are discussed as follows.

Firstly, the current study used GPS as the positioning tool. The advantage of GPS is that no assistant device should be included in the system, because GPS is a built-in function of modern PDA. The main problem of the GPS, however, is that it takes over 30 seconds to initialize the positioning function. GPS is also influenced by the weather. For example, a raining or cloudy day is not suitable for using the proposed system in the outdoor learning, since the signal is unstable and it is hard to position the learner's location. In days of such a bad weather, the active sensor or RFID techniques can be used as the alternative positioning tools.

Second, in the current study, the improvement of the experimental group is an integrated effect. To specify the effects of each method, in future research, two additional groups, for instance GPS only and Flow learning method only, may be designed.

Furthermore, as this study only investigated two elementary classes in the Mangrove Conservation Area in Bali, Taipei County, Taiwan, the generalizability of the current findings may remain restricted. Therefore, this approach can be replicated in different learning environments, such as national parks, MRT stations, or shopping malls, to provide different learning contexts.

Lastly, in order to achieve more robust results, more data should have been collected for this study. In future studies, more qualitative observations will be needed to further explore learners' learning behavior and attitudes.

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# Appendix A

The results gained through the computation of the latitude-longitude distance formula (formula 1) will help in comparing an individual learner's location with where all the learning sites in the system database to reveal the nearest site accessible to the learner.

$$D_i = \cos\left(\sin(Lat_c)\times\sin(Lat(LL_i)) + \cos(Lat_c)\times\cos(Lat(LL_i))\times\cos(Long_c - Long(LL_i))\right)\times R, \quad i = 1,\ldots,n \quad (1)$$

$R$ is the radius of the earth, approximately 6371 km. $Lat_c$ and $Long_c$ are the latitude and longitude of the learner's present location. $Lat(LL_i)$ and $Long(LL_i)$ are the latitude and longitude of the chosen learning location $i$. $D_i$ is the relative distance between the learner's present location and the chosen learning location $i$.

$$SN = \{ j \mid D_j \text{ is the minimum value of } D_i, \text{ and } D_j \le 10, i = 1,\ldots,n \} \quad (2)$$

$SN$ is the serial number of the chosen learning location, which is the nearest location to the learner. It is important to note that $D_j$ must be no more than 10 meters (the tolerable error of GPS technique).

When a learner is on the field, the PDA inbuilt with the aforementioned system in his/her hands will obtain the coordinates of the learner's location via GPSID, and then search relevant GPS coordinates of the curriculum in the positioning service database as shown in Figure 16. Next, the relative distance between each learning environment is calculated by formula (1), the nearest environment to the learner's location is identified by formula (2), and the serial number is sent to the learning device. Then, the learning system can find the relevant learning materials in the database and present them to the learner.

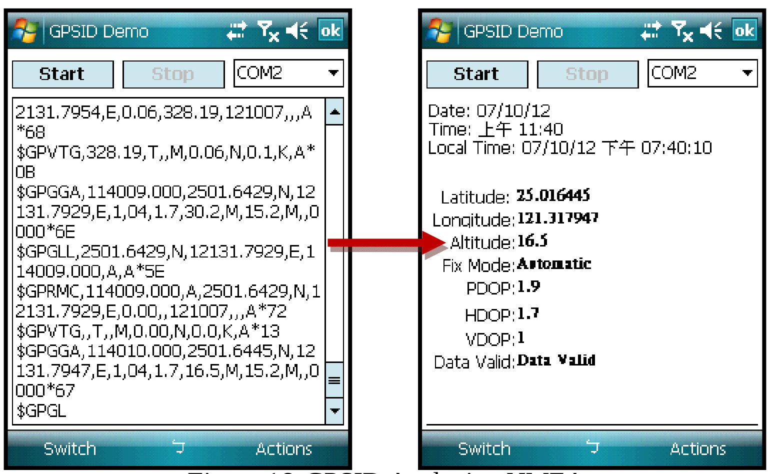

*Figure 16*. GPSID Analyzing NMEA

## Appendix B

**Post-activity Questionnaire**

| | Questions | SA | A | N | D | SD |
|---|---|---|---|---|---|---|
| 1. | I am happy with the route designed for the task. | | | | | |
| 2. | I am happy with the assignments of the task. | | | | | |
| 3. | The interface of the learning system is user-friendly. | | | | | |
| 4. | The weight of the learning device is suitable for traveling. | | | | | |
| 5. | I am satisfied with the stability of the learning system used in the task. | | | | | |
| 6. | I am satisfied with the speed of the positioning technology in the task. | | | | | |
| 7. | I am satisfied with the learning procedures in the task. | | | | | |
| 8. | I am satisfied with the games played in the course of the outdoor ecology learning. | | | | | |
| 9. | I am satisfied with the functions (photo-taking and the touch screen) in the system. | | | | | |
| 10. | Generally speaking, I am happy with the outdoor ecology learning. | | | | | |

Note: SA=Strongly Agree (5), A=Agree (4), N=Neutral (3), D=Disagree (2), SD=Strongly Disagree (1)