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LONG PAPER

Design and development of a location-based mobile learning system to facilitate English learning

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Abstract Rapid technological developments along with the popularity of the Internet and mobile devices in recent years have allowed learners to undertake learning outside the confines of the physical classroom and immerse themselves in actual locations and situations. This has led to a proliferation of research in this field together with the design and development that integrate the use of mobile devices, allowing students to undertake mobile context-aware learning. In this study, 64 Taiwanese tertiary students evaluated a learning system about plants in the English language. This location-based mobile learning system to facilitate English learning was based on mobile context-aware learning and related theories. The analysis, design, development, implementation, and evaluation model was used for the system development. Analysis of users' requirements indicated that the majority of subjects preferred teaching materials with text and images presented on web pages on mobile devices, and that the user interface should be simple. Feedback from the evaluation of the system included suggestions to improve the maps, words, and images provided, as well as the sensing range of the global positioning system. In addition, providing forum feedback and an audio guide may be strategies to enhance users' experience of using the system. After modifications, the final product was a fully functional system for learning about plants in English. Mobile learning is the future developmental trend in the field of education. It is anticipated that the design and development of the proposed system will serve as a reference for other researchers and future developments in mobile learning systems.

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1 Introduction

The Horizon Report [1–3] highlighted mobile learning as the future developmental trend in the field of education. Currently, various curricula are available for learning through mobile devices. Over the past few years, rapid technological developments and the proliferation of the Internet and mobile devices have facilitated the development of the context-aware learning method, allowing the learning process to go beyond the confines of the physical classroom. Many researchers have also developed varying contents for learning through this method [4, 5].

The context-aware learning method encourages learners to think through and reflect on acquired knowledge before applying it [6–8]. Research has shown that context-aware learning with computers can improve learning effectiveness [9, 10]. Research on context-aware learning supplemented by the use of mobile devices has also confirmed that this learning method has a positive impact on learning achievement [4, 5, 11, 12].

Most of the existing context-aware learning research has utilized RFID [13, 14] technology; however, the potential of the global positioning system (GPS) has been left unexplored. Compared with RFID, the wide sensing range of GPS may help learners engage in learning activities without the problems of finding RFID tags. Moreover, GPS is readily available on most smartphones without the need to purchase and allocate RFID devices. Therefore, this study sought to develop a mobile context-aware learning platform, incorporating GPS location data, and applying it in an appropriate context.

The aim of the study was to understand the degree of familiarity that Taiwanese tertiary students have with plants in the English language, as well as their interest in learning about this topic. The results from a survey conducted with 64 tertiary students showed that the majority of the students were unfamiliar with the topic. On their ability to correctly state the names of plants in English, 57 students (89 %) responded that they were not or might not be able to do so. The survey also found that 52 students (81.2 %) were willing to learn about the topic if related teaching materials were available. The authors believe that in the future, English-language learning content on plants can be incorporated into the teaching curricula for students in their school education. Further, after gaining a deeper understanding of botanical knowledge, students are likely to be more specific when answering questions on plants, instead of using generic nouns. Hence, it was decided to use a course on learning about plants in English as the basis to develop a mobile context-aware learning platform, incorporating GPS location data, and applying it in an appropriate context. At the end of this research, it is hoped that not only theoretical insights into the use of GPS location-based mobile learning, but also feasible suggestions that would help implement a more engaging experience for developers involved in the field of mobile context-aware learning will be provided.

2 Related research

This study aimed to develop a mobile context-aware learning system that teaches about plants found on a university campus, in English. The survey subjects were undergraduates and graduates. It can be argued that the incorporation of context-aware learning in the curricula would better help learners apply the knowledge already acquired. This section discusses theories related to context-aware learning, followed by a review of research on context-aware learning integrated with computer-based and mobile-based approaches as well as the impact of these approaches on learning effectiveness.

2.1 Context-aware learning

By definition, context-aware learning refers to the situation in which learners enter into real-life situations so that they can directly immerse themselves in the environment and sharpen their skills. This approach facilitates learning because of the close relationship between learning and context [6]. The theory of contextual learning emphasizes that knowledge acquisition is closely linked to the context of the learning activity. It aims to allow learners to investigate knowledge and learn to use it within a realistic and appropriate environment [6, 7]; in other words, being in a real-life situation facilitates the learning process [15]. Context is part of the learning contents, so learners gain a clearer understanding of knowledge through the interaction between the context and the activities taking place within it. Even though contextual learning provides learners with an appropriate environment to learn, Brown et al. [6] indicated that a guide is still necessary to help learners fully understand the contents of the knowledge. Learning performance is achieved through using and reflecting on knowledge, similar to the notion of learning by doing.

Brown et al. [6] considered context and learning to be closely associated, with learning being facilitated by placing the learner in real-life situations. Researchers believe that this method enables learners to think and solve problems more adequately, resulting in improved learning effectiveness. This method also prevents knowledge from rigidifying and makes the learning process more meaningful through the application of knowledge [8].

A previous study found that when a context-aware learning system was used in the context of vocabulary learning, the learners' perceived ease of use and usefulness of the system had a significant impact on their attitudes toward its usage [16]. Thus, when the perceived ease of use and usefulness improved, the learners were more enthusiastic about using the system. Tan et al. [13] developed a context-aware learning system to facilitate outdoor teaching for elementary school students. In addition to improved learning performance, significant changes were observed in terms of the perceived ease of use and usefulness of the system, indicating that the learners found it easy to use and thought that it was pertinent to the learning process.

Another method similar to the concept of context-aware learning is legitimate peripheral participation (LPP), as proposed by Lave and Wenger [17], which similarly stresses the importance of real-life situations in learning. LPP refers to the process in which the learner is immersed in real life, progressing from initially being at the periphery and participating only as an observer to being fully involved in in-depth learning and the application of knowledge. LPP works in the same manner as an apprenticeship: The learner participates and engages in a real-life situation, learns through the guidance provided, and eventually functions in the real working environment.

With today's technological advancements, context-aware learning can also be carried out through simulations created on a computer or with the use of mobile devices when physically present in real-life situations [5, 11]. The more realistic the situations and supplementary teaching materials are, the better the learner is able to learn. The following sections will look at various studies conducted on the traditional computer-based and mobile learning methods.

2.2 Web-based and computer-based learning

A common method for simulation learning is traditional web-based and computer-based learning. For example, Granlund et al. [18] developed a micro-world supporting command and control training system to allow learners to experience a complex phenomena in a web-based environment. Hill et al. [19] considered web-based learning to be advantageous. The learning method is customizable to suit the needs of different learners, thereby facilitating individual learning, while also catering to the learning style of the majority of learners. The use of web pages as part of the teaching method was found to be even more helpful. For Berglund [20], the computer-based approach that simulates different situations helps learners to grasp complex concepts better. Further, the use of computer-based simulations conserves learning resources. Hence, traditional computer-based learning is an effective learning method because of its adaptability, ability to conserve learning resources, and application of knowledge in accordance with situational understanding.

Although traditional computer-based learning usually allows learners to undertake learning on a computer or the Internet, not all courses incorporate the context-aware method. This section thus focuses on incorporating the use of computers or Web sites into the context-aware learning method, which is primarily concerned with providing an environment that allows learners to think about or to apply the acquired knowledge. Hsu [9] examined the characteristics of context-aware learning, using Web sites to help junior high school students understand the principles of rainbow formation. This method had a significant impact on the students' learning achievement. Subsequently, Chang et al. [11] created the WebQuest Web site, which has preset situational contents to help elementary school students learn about the concepts of waste classification and recycling resources. Research found that the use of WebQuest, combined with context-aware learning, enhanced learning performance.

Previous research led to the development of various learning methods based on simulated contexts and traditional computer-based learning, applicable to multiple disciplines. Regarding learning English as a foreign language in particular, Shih and Yang [10] trained undergraduates to improve their verbal abilities through situations constructed using the 3D Virtual English Classroom (VEC3D), which allows learners to communicate with one another over the Internet. In another study by Chang [21], the use of Web sites combined with self-monitoring was effective in terms of improving undergraduates' English reading ability. Tsai [22] made use of situational Web sites and other collaborative learning methods to help English teachers further improve their language abilities.

In the above studies related to learning English as a foreign language, learners were able to create different learning environments through the Web sites, thereby improving their learning effectiveness [10, 11, 22]. However, the use of computer-based learning has led to negative findings as well. For example, Piccoli et al. [23] compared the results of two groups of learners: One used a web-based virtual learning environment, while the other followed traditional learning methods. The authors found that learners in the traditional learning group scored higher marks. Some of the learners in the web-based virtual learning group attributed their poor performance to their inability to adapt to a learning environment that accorded them such a high degree of freedom.

In summary, traditional computer-based learning is applicable to various disciplines. Through computer-simulated scenarios, learners can directly reflect on what they have learned and how to apply the knowledge, thereby enhancing their learning achievements. Even though the findings of some studies have proved otherwise, computer-based learning can generally lead to good results if used appropriately.

2.3 Mobile context-aware and ubiquitous learning

By definition, context-aware learning refers to the immersion of learners within real-life situations in which they are directly affected by the environment, thereby sharpening their skills in the learning process. Context-aware and ubiquitous learning (u-learning) is similar to the mobile context-aware learning (MCL) system developed in this study, because the system incorporated real-life campus plants into mobile devices to facilitate English learning. After reviewing past studies, Chang et al. [11] concluded that the advantages of the MCL system include the ability for learners to experience and observe real-life situations and to gain complete knowledge of the topic under study. In so doing, learners grasp abstract thoughts and concepts, thereby achieving greater learning effectiveness.

In the past, schools carried out context-aware learning mainly in the form of outdoor teaching, where students gathered to listen to a guide or a teacher speak about a particular subject. Examples included visits to museums or outdoor ecological parks [24]. However, in this scenario, learners may not be able to have personalized experiences, because the itineraries of the field trip are determined by the teachers. As a result, learners might not obtain the desired learning achievement. Therefore, if the mobile learning method is applied to context-aware learning, the convenient and practical aspects of the technology must be exploited to detect the precise location of the learners, for example, or to determine the learning contents or interaction methods best suited to them.

Many current studies aim to combine the context-aware and mobile learning methods, demonstrating the greater convenience of this combined method compared with traditional situational learning. Schiller and Voisard [25] suggested that mobile context-aware learning can be conducted via active or passive context awareness. With active context awareness, the system is in control, keeping track of changes in the learner's context and taking the initiative to send the appropriate learning information. With passive context awareness, however, the learner is in control. When the learner moves throughout the environment and identifies something of interest, a request is made to the location-based system for the delivery of the relevant information.

Examples of various MCL systems developed by researchers are elaborated below. Firstly, a system for learning mathematics developed by Zhao et al. [26] takes into account the learner's experience and learning environment, and then provides guidance on the solution to the problems using images, thereby increasing learning effectiveness. Hwang et al. [4] applied the method to the operation of laboratory instruments. The operational difficulties involved in this, necessitating the supervision and guidance of experienced users, resulted in the heavy consumption of human resources and a lack of adequate practice for beginners. An expert system based on the context-aware approach displays the appropriate experimental procedure and contents to the learners. This not only reduces the amount of labor involved and costs incurred due to experimental errors, but also enhances the learning effectiveness. Hwang et al. [5] combined the mobile context-aware and collaborative learning methods with mind mapping for elementary school students to learn at a butterfly park. Collaborative learning refers to the use of the division of learning tasks, mutual sharing, communication, and the provision of support to achieve common learning goals [27]. In addition to enhancing the learners' achievements, their self-efficacy (i.e., judgment regarding their competence to undertake a specific task [28]) in the use of computers also improved. Hwang et al. [12] developed a u-learning platform for students to acquire knowledge about computers and learn how to self-assemble the machines. This learning platform improved learning effectiveness and reduced learning time. Lastly, Chang et al. [11] combined WebQuest with context-aware learning. WebQuest provided information and assignments through web pages to elementary school students, who conducted mobile learning and on-site observations to complete the stipulated assignments. This method allowed students to have a more satisfactory and engaging learning experience. As these studies show, the MCL method is applicable to a variety of topics, and when integrated into teaching in real-life situations, it enhances learning effectiveness. The method is likely to be a future trend in learning. Therefore, the purpose of this study was to develop a mobile context-aware learning system that integrates real-life situations and teaches about plants found on campus, in English.

3 Design and development processes based on the ADDIE model

This study focused on the development process and evaluation of the system created by the research team for Taiwanese tertiary students to learn about plants in English. As shown in Fig. 1, the design and development of the location-based mobile learning system was based on the analysis, design, development, implementation, and evaluation (ADDIE) model [29, 30]. This model is a framework for building teaching materials in five phases and is widely adopted by instructional designers and training developers. The detailed processes of each phase are described in the following sections.

3.1 Analysis phase

To comprehend users' level of English with regard to the plants and their expectations regarding the functionality and learning contents of the system, the research team conducted a questionnaire to obtain their feedback and suggestions. The questionnaire was administered twice online in 2012, with the subjects being undergraduates and graduates. The first questionnaire, with 51 valid responses received, focused solely on subjects' familiarity with plants in English. The second, dealing with the subjects' proficiency in the English names of plants and system requirements, had 64 valid responses.

The second questionnaire had four main aims. The first aim was to understand the subjects' familiarity with the English names of plants, and their interest in learning about the topic. The second aim was to identify the types of

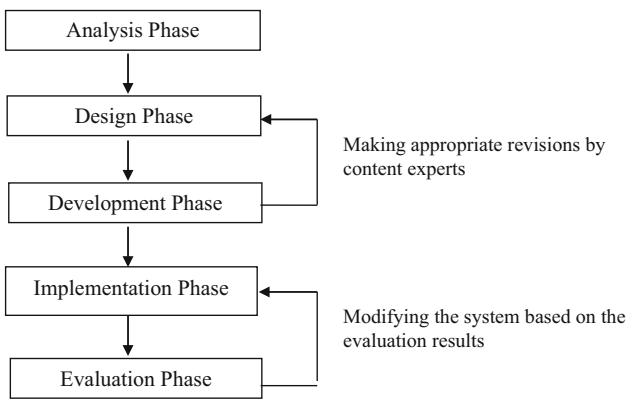

Fig. 1 ADDIE model

smartphones used by the subjects, the operating system (OS) of their mobile devices, and their past experiences with MCL. The third aim was to determine the respondents' interest in using the teaching contents, and their impression of the presentation format of the user interface. Finally, the questionnaire aimed to obtain suggestions and recommendations regarding the system functionality and contents.

The educational qualifications of the subjects are stated in Table 1. Of the valid responses received during the first questionnaire, the majority of students were graduates (38 or 74.5 %) and the remaining 13 (25.5 %) were undergraduates. In the second questionnaire, graduates and undergraduates comprised 68.7 % (44) and 31.3 % (20), respectively.

3.1.1 *Proficiency in the English plant names and interest in learning*

The results of the two questionnaires indicated that the subjects' degree of familiarity with the plants was low. In fact, the majority felt that they would not be able to correctly state the plant names in English (for example, pine or banyan trees). In the first and second questionnaires, 23 (45 %) and 37 (57.8 %) of subjects, respectively, stated that they were very unfamiliar with the topic, while 25 (49 %) and 23 (35.9 %) were unfamiliar (Table 2). Only three (6 %) and four (6.3 %) subjects, respectively, indicated that they were either familiar or very familiar. Overall, more than 90 % of the subjects were unfamiliar or very unfamiliar with the topic.

In terms of the ability to state plant names in English correctly, 25 (49 %) and 39 (60.9 %) in the first and the second questionnaires, respectively, indicated that they would definitely not be able to do so (Table 3), while another 25 (49 %) and 18 (28.1 %) stated that they might not be able to do so. Only seven (13.7 %) and six (9.4 %) subjects, respectively, thought that they might be able to do so. In both questionnaires, only one subject (2 and 1.6 %, respectively) responded that he/she was able to state the answers correctly.

Despite this lack of familiarity, there was a high level of interest among most subjects to learn about the plants in English (Table 4). In the first and the second questionnaires, 3 (5.9 %) and 10 (15.6 %) subjects, respectively, said that they were very willing, while 33 (64.7 %) and 42 (65.6 %) were willing. In the first questionnaire, 25.5 % of respondents were unwilling and 3.9 % very unwilling (15 subjects in total), compared with 18.8 % (12 subjects) for these two categories in the second questionnaire.

Table 1 Educational level of subjects in the first and the second questionnaires

Questionnaire respondents	First questionnaire		Second questionnaire	
	Number	%	Number	%
Undergraduates	13	25.5	20	31.3
Graduates	38	74.5	44	68.7
Total	51	100	64	100

Table 2 Familiarity with plant names in English

Degree of familiarity	First questionnaire		Second questionnaire	
	Number	%	Number	%
Very unfamiliar	23	45.1	37	57.8
Unfamiliar	25	49.0	23	35.9
Familiar	2	3.9	4	6.3
Very familiar	1	2.0	0	0
Total	51	100	64	100

Table 3 Ability to state plant names in English correctly

Degree of ability	First questionnaire		Second questionnaire	
	Number	%	Number	%
Definitely not	25	49.0	39	60.9
Probably not	18	35.3	18	28.1
Probably	7	13.7	6	9.4
Definitely	1	2.0	1	1.6
Total	51	100	64	100

Table 4 Interest in learning about plant names in English

Level of interest	First questionnaire		Second questionnaire	
	Number	%	Number	%
Very low	2	3.9	0	0
Low	13	25.5	12	18.8
High	33	64.7	42	65.6
Very high	3	5.9	10	15.6
Total	51	100	64	100

3.1.2 *Types and OS of mobile devices and experiences with MCL*

Regarding the rate of smartphone use among subjects, the OS of their mobile devices and their experience with MCL, the results showed that the ownership of smartphones was high (Table 5), with many subjects having prior experience of learning through smartphones. The majority had either

Table 5 Ownership of smartphones

Ownership	Number	%
Yes	41	64.1
No	23	35.9
Total	64	100

Table 6 Experience of using smartphones for learning

Experience	Number	%
Yes	25	39.1
No	39	60.9
Total	64	100

Table 7 Smartphone operating system

Operating system	Number	%
Android	27	42.2
Apple iOS	13	20.3
Windows	3	4.7
Others	21	32.8
Total	64	100

Table 8 Interest in having interactive features on the mobile learning interface

Level of interest	Number	%
Very low	1	1.6
Low	8	12.5
High	37	57.8
Very high	18	28.1
Total	64	100

Table 9 Interest in the learning content to be presented via text and images

Level of interest	Number	%
Very low	1	1.6
Low	2	3.1
High	35	54.7
Very high	26	40.6
Total	64	100

Table 10 Interest in having simple prompts in Chinese

Level of interest	Number	%
Very low	2	3.1
Low	4	6.2
High	30	46.9
Very high	28	43.8
Total	64	100

Android or Apple iOS running on their mobile devices (Tables 6, 7).

Since both Android and Apple iOS were popular smartphone OSs, a learning Web site was created and adapted to mobile devices as the research tool, which could be accessed by users on different platforms.

In addition, the survey contained open-ended questions on the subjects' experiences with MCL, the learning contents studied, as well as suggestions to improve their learning experiences. An analysis of responses indicated that most of the subjects had used MCL for learning languages, with English being the most popular language. The learning process generally involved looking up and learning vocabulary (e.g., learning a new word every day) or using Test of English as a Foreign Language (TOEFL) and Test of English for International Communication (TOEIC) applications. Following English, learning Korean and Japanese was next in popularity; a minority of subjects used MCL to study commerce or medicine.

Most subjects highlighted the need to pay attention to the relatively small screen size of mobile devices, which affects learners' ability to read the information properly. Further, the subjects felt that the network quality should be good, slow data transmission avoided, and the source and credibility of the learning materials ensured; these findings were consistent with the results of a retrospective study conducted by Song [31]. Hence, in terms of implementation, attention was paid to appropriate font sizes and the presentation of key points. A simple interface with a clean and uncluttered layout was also maintained, to facilitate reading. When collating data to prepare the teaching materials, textbooks, and Web sites with good credibility and reputation were selected as sources.

As for the learners' interest in using the interface, having interactive functions on the learning Web site was a popular preference among subjects, with 55 (85.9 %) indicating that they were very willing to use such features (Table 8).

Given the relatively small screen size of the mobile devices, it was important to know whether the text and images used to present the learning content would facilitate learners' reading and help them focus. The results indicated that 61 (95.3 %) were willing to learn using a mode that integrated both text and images (Table 9). Considering the burden on learners with varying levels of language proficiency if all learning content was stated in English, providing some prompts in Chinese was suggested to facilitate learning. An overwhelming majority (58 or 90.7 %) expressed a high level of interest in learning if such prompts were provided (Table 10).

3.1.3 Interest in using the learning content

The subjects' interest in making use of the learning content and the presentation mode was addressed in the survey. As shown in Table 11, 60 (93.8 %) of the respondents were willing to learn about plants located on the university campus and their relevance to the university's history. A very significant proportion (61 or 95.3 %) was also willing to learn about additional botanical knowledge, for example, the plants' growth environment and characteristics (Table 12).

Table 11 Interest in learning about plants and their relevance to the university's history

Level of interest	Number	%
Very low	2	3.1
Low	2	3.1
High	48	75.0
Very high	12	18.8
Total	64	100

Table 12 Interest in learning additional botanical knowledge

Level of interest	Number	%
Very low	1	1.6
Low	2	3.1
High	47	73.4
Very high	14	21.9
Total	64	100

3.1.4 User suggestions regarding the functionality and contents of the system

Open-ended questions were used to invite subjects to comment on the functionality and interactivity of the system, as well as the teaching materials on plants, in English. As for the system functions, nine subjects suggested incorporating mini-quiz games, with answers and explanations provided. Seven suggested providing feedback and interaction through questions and answers, or having discussion forums. Six subjects felt that the inclusion of mini-games, such as word memorization games, in the learning process would make the system more attractive. Nevertheless, a few subjects cautioned against including too many functions; instead, they preferred a clean and simple user interface, as they were concerned that transmission speed would be compromised if the system had too many functions.

Regarding the learning content, ten subjects preferred the information on plants to be related to the uses of the plants as well as their occurrence in daily life. Other subjects felt that it would be good if the contents incorporated information on plants that had special features on the campus or with significance to the university's history. They also wanted to learn about the symbolism and cultural significance of the plants. Although the focus was on the learning contents, there were still six subjects who expressed a desire for the materials to be presented in an animated form or with supplementary audio instructions to facilitate learning.

3.1.5 Summary of system requirements analysis

The analysis of the findings from the survey showed that although most of the subjects were unable to state the plant names in English correctly, they were willing to learn about the topic. Hence, the main content for this study was aimed at learning about plants in English. Smartphones were the predominant form of mobile devices used. To allow users to access various platforms and OSs, the system should be presented in the form of web pages. In accordance with the subjects' suggestions, the user interface should be simplified.

The subjects' very high level of interest in acquiring botanical knowledge integrated with the history of the university and its campus, as well as their preference for the integrated use of text and images were also taken into consideration. Prompts translating the English words were also provided. To meet the subjects' request for interactivity during the learning process, a discussion forum was set up in the system.

3.2 Design, development, and implementation phases

This study aimed to design an MCL system to learn about plants found on a university campus in English. Through the system, it was hoped that learners would recognize the plants on campus, learn their botanical names in English, and be familiar with the environment and historical significance of different parts of the campus. The system was developed based on the users' system requirements collated from the two questionnaires and the guidelines suggested by Shneiderman et al. [32].

3.2.1 Development of the learning material

Plants found on the campus were selected as the topic for designing a learning course in English. The surveys indicated that the majority of subjects were not proficient in the English plant names, but were interested in learning them. Hence, this topic was decided on as the main learning content. The content experts chosen were current English-language teachers with more than 5 years of teaching experience in junior high and high schools. They felt that it

would be difficult to present the botanical terminology if the researchers were to use teaching materials originally prepared in Chinese and then translated into English, so suggested seeking English-language professional teaching materials on plants, and then adapting and editing the content to meet the needs of the study. Following their advice, information was obtained from the *Plants of Taiwan* Web site [33] and then the contents were adapted accordingly. The *Plants of Taiwan* is an integrated query Web site on Taiwan's botanical information, established by the Institute of Ecology and Evolutionary Biology of the National Taiwan University. The project leader of the *Plants of Taiwan* is a professor of Botany, specializing in broad-leaved forests and flora of Taiwan, therefore ensuring the validity and credibility of the Web site.

Questionnaires were used to collect data and suggestions from the subjects before analyzing the learning content and requirements. From the findings of the analysis and following discussions with e-learning, instructional design, and instructional technology professionals, the researchers proceeded to design, develop, and implement the teaching material. The research team went around the campus to select suitable locations for learning. From the signs put up by the university administration, an understanding was gained from the names of the various plants and their botanical characteristics at the selected locations. The researchers then referred to the *Plants of Taiwan* system to compare and verify the plant species before selecting the requisite English contents. However, the system contents were overly technical and specialized, so the advice of content experts was sought to make appropriate revisions, thus rendering the content more relevant to daily life and more suited for undergraduate reading.

Following the analysis of the questionnaire responses, it was found that a high proportion of subjects preferred that the special characteristics of the campus be integrated into the contents (Table 11). Accordingly, those locations on campus with special features or of historical significance were selected, and the information together with the botanical contents was presented. Details of the history and special features of the campus were translated in English by the content experts.

3.2.2 *System implementation and design of the user interface*

The learning system was developed in-house by the research team [34]. When users visited the various locations on the campus, they used their smartphones to go online and determine their positions via the global positioning system (GPS) and the third-generation (3G) telecommunication networks. Data on their location were matched against the GPS position of the various learning locations. In cases of a match, the relevant information and learning contents were then provided to the learners. The configuration of the system is shown in Fig. 2.

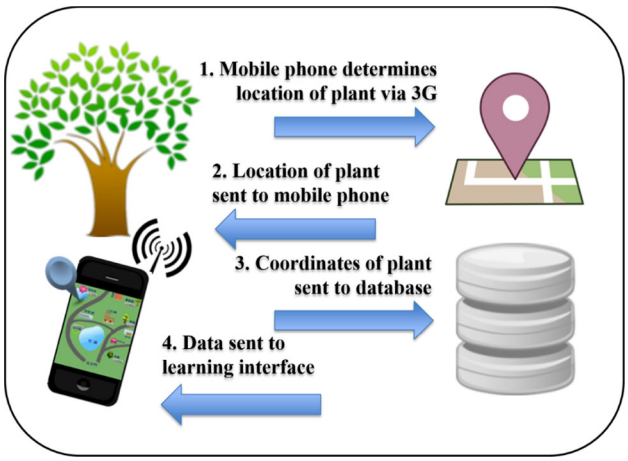

Fig. 2 System configuration

The design of the system's user interface was made with reference to the users' requirements and to five of the eight rules of interface design as stated by Shneiderman et al. [32]: (1) strive for consistency, (2) cater to universal usability, (3) permit easy reversal of actions, (4) support internal locus of control, and (5) reduce short-term memory load. Consistency was ensured in the use of colors and typography layout in the interface as well as font sizes and colors. The layout and contents remained the same regardless of where the users clicked on the screen. The Web site was designed to meet the requirement of universal usability, and as such, could be viewed using any commonly found mobile browser. The method to cancel any operation was made simple to permit easy reversal of actions. In the case of errors in any of the links, subcategories, or supplementary pages, users could easily navigate back to the previous web page or click the correct link to access the desired page.

The internal support and controls for the Web site also ensured consistency in the displayed layout and colors. By minimizing the number of changes when moving between the various web pages and supplementary pages, it was possible to reduce the sense of maladjustment and discomfort to users. In addition, the research team wanted to reduce the load on users' short-term memory. Since most people's immediate capacity memory falls within the range of seven plus or minus two elements [35], the number of buttons available to users was limited to five to avoid an excessive burden on their memory processing capacity. Figures 3, 4, 5 and 6 present images of the learning interface, contents, and functionality, as well as on-site photographs of a learner using the system.

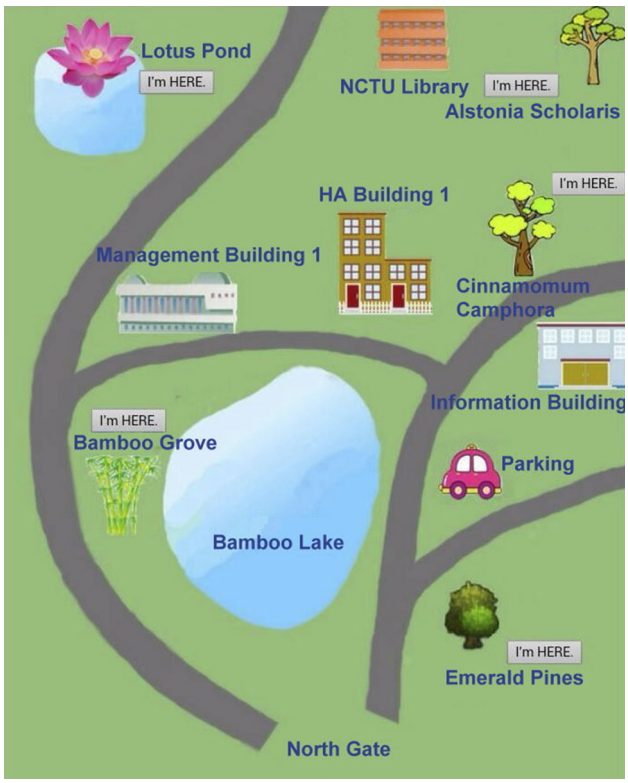

Fig. 3 Mobile learning interface

Fig. 4 Mobile learning interface: contents

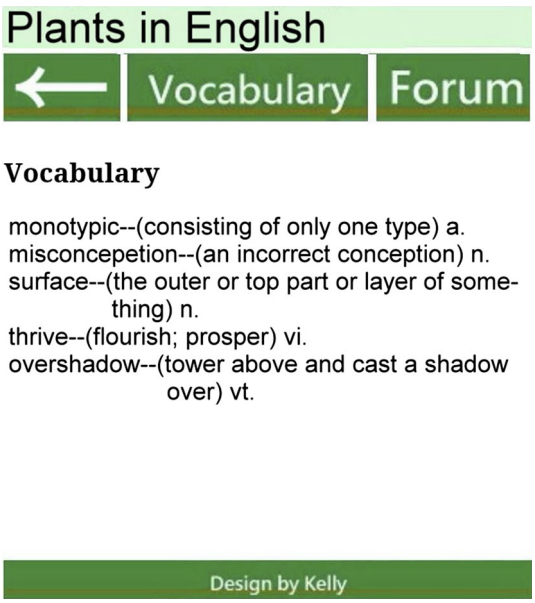

Fig. 5 Mobile learning interface: vocabulary

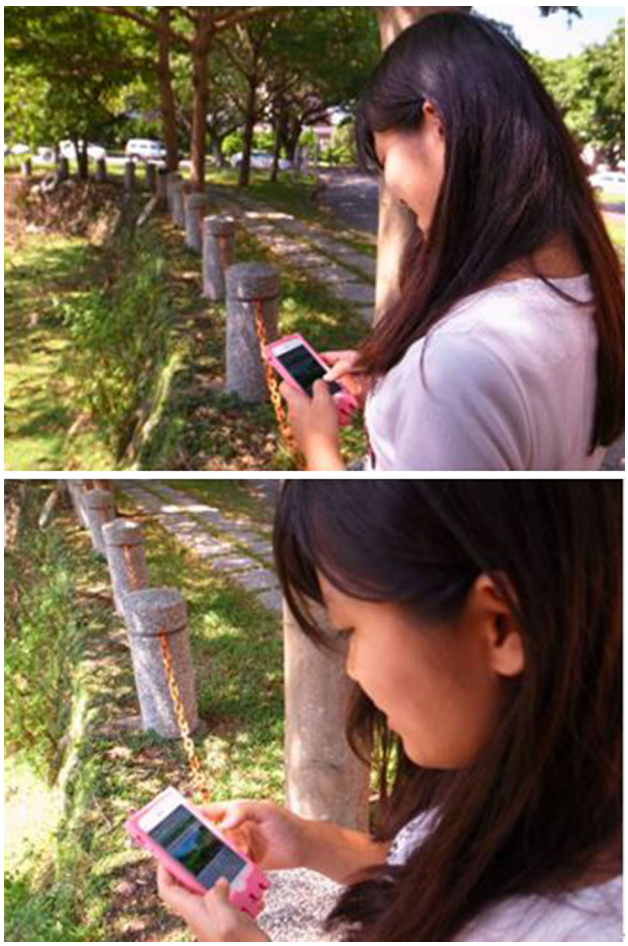

Fig. 6 A learner engaged in mobile learning

Table 13 Comparison of modifications made

Before	After
Unclear location labels on the map	Modifications accordingly made (Sect. 3.3.1)
Uncaptioned photos	Captions added (Sect. 3.3.2)
Difficult to determine location using global positioning system	Global positioning system improved (Sect. 3.3.3)
Pagination of words and other issues	Modifications accordingly made (Sect. 3.3.4)

3.3 Evaluation phase

In this phase, individual learners were approached to conduct evaluations to understand the problems encountered when using the system and to obtain any suggestions for improving the system. Opinions and comments obtained from the users were later incorporated when the system was modified. A comparison of the modifications made to the system is shown in Table 13 and elaborated below.

3.3.1 Locations on the map should be easily identifiable by users

Through the interviews, the difficulty for users to identify some of the locations on the map of the homepage was realized. Users who were unfamiliar with the campus did not know the exact location of the plants. Through the actual observations, it was noticed that learners had many difficulties locating the area with the camphor trees because of the erroneous labeling of the building located in the vicinity, which confused them. For example, one location that was not easy for the learners to locate was originally labeled as the Zhongzheng Hall. The reference building was later changed to the Computer Center, which was then easily identifiable.

The learners also commented that on the map, the location label for the area with the *Alstonia scholaris* (blackboard trees) was unclear. Even after they arrived at the correct location, they were unable to match their existing location with the photograph of the location provided by the system. Further, these trees cover a relatively large area, making it difficult for the learners to identify the exact location. In view of the comments, the original photograph was replaced with two photographs to make the location more identifiable (Fig. 7). Learners who originally made the comment were then approached, to verify that the replacement photographs were more appropriate and useful.

3.3.2 Captions or explanations should be provided for the images

During the user tests, the learners discovered that when accessing the web pages with images of the plants, the images were not accompanied by any captions or explanations of the exact plant part. As such, the learners' understanding of the plants was not enhanced by the images. Appropriate modifications were once again made (Fig. 8).

3.3.3 Sensing range of GPS positioning should be enlarged

The learners provided feedback that they had difficulty determining the exact GPS location of the lotus pond and the area with the *Alstonia scholaris* due to these two locations being adjacent to other learning locations. When setting up the GPS positioning, and due to considerations about the potential overlap of locations, it was decided to make the sensing range more specific. Based on the feedback, however, it was also decided to enlarge the sensing range of the two affected locations without causing any overlap, so that learners could successfully locate them.

3.3.4 Other issues and suggestions

Another issue highlighted by learners was poor pagination. The web pages on the individual words and contents were separated, making reading difficult. This arose from a technical constraint: The contents had to be separated into multiple web pages because of the limited screen size of the mobile devices. The aim was to avoid placing too much information onto a single web page, which would make it cluttered and difficult to read. Since this is a hardware constraint, the solution will have to depend on future enhancements, such as higher screen resolution, made to suit the performance of the hardware and program execution of the system.

The results of the user tests brought to light the aforementioned issues relating to the system. These were subsequently rectified, based on the suggestions made by learners.

4 Conclusions

In this study, 64 Taiwanese tertiary students evaluated a system developed for learning about plants in English. Subsequently, a location-based mobile learning system to facilitate English learning was designed, based on MCL and related theories. An analysis of users' requirements indicated that the majority preferred the teaching content to be presented in the form of both text and images on the mobile devices. The design and the development were based on the ADDIE model [29, 30], which provides a guideline to create learning material in the order of analysis, design, development, implementation, and evaluation. The results of the system evaluation entailed making

Fig. 7 Modified photographs of locations to be identified: before (*left*) and after (*outlined in red*)

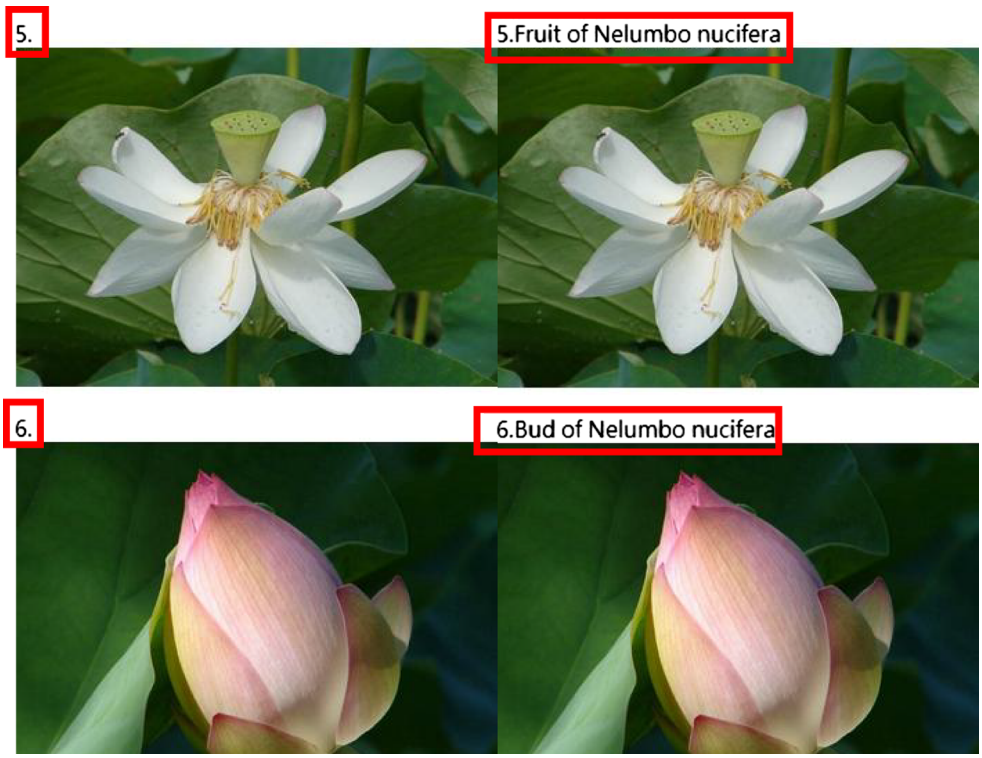

Fig. 8 Modified photo captions (*outlined in red*): before (*left*) and after (*right*)

modifications to the maps, texts, and images provided, as well as the sensing range of the GPS positioning. After implementing all of the modifications, a fully functional system for learning about plants in English was created. As MCL is a future development trend in the field of education, the research team therefore believes that the design and development of this system and the incorporation of GPS in an MCL environment can serve as a reference for other researchers and the future development of MCL-related systems. For example, developers may adapt the design flow (i.e., the ADDIE model) of this study, conduct similar evaluations, and implement the suggestions from the results of this study.

5 Future work

In addition to system evaluation, future studies may investigate the effects of motivational factors, such as self-efficacy and self-regulation, on student achievement with

this location-based mobile learning system to understand how such a system benefits students [36]. In addition, based on the interviews with learners and experience during the development process of the system, a list of additional functions to be included in future systems was collated to help to achieve even better results.

5.1 Forum feedback

Some learners stated that they did not feel as though they were engaged in a proper learning process because the forum did not provide instant feedback. In hindsight, this resulted from individual participants doing the experiment separately, so there were not many other participants online to respond to queries posted in the forum at the same time. One suggestion was for a group of learners to set off and carry out the experiment at the same time, similar to how classes are conducted in elementary schools. This would facilitate more rapid responses to queries raised on the forum. An alternative would be to integrate the learning system with a Facebook community, which could facilitate learners receiving instant responses and feedback. Learners who did not receive any feedback could still use the Facebook community as a means of learning about the plants.

5.2 Learning through gameplay

For this study, only five relatively close locations were selected, not including the learning locations near the south gate of the campus, considering the time constraints and in order to ensure that the experiment was not too physically demanding for the participants. A greater number of learning locations could be included in the future, especially those with special significance to the university, so that learners could better understand their alma mater. Furthermore, the learning process could incorporate simple gameplay to make it more interesting, so that learners do not simply read information on their mobile devices.

5.3 Future developments

The MCL system presented aimed to teach undergraduates and graduates about various plants located on the university campus in English. However, there is also potential to apply this system to elementary and middle school students. Another suggestion is thus to implement it in the various ecological parks around the country since their widespread geographical distribution would facilitate GPS positioning. Tourists and visitors could then use the system to educate themselves about plants or other aspects of the parks' ecological system.

5.4 Identifying locations on maps

The map prepared did not provide any prompts to help participants identify the learning locations. As a result, the learners faced the additional burden of having to identify the correct locations on their own. The MCL system could thus be enhanced by providing an audio prompt to alert learners that they have entered a zone with available learning content. Alternatively, a message could be shown on the screen of the mobile devices to inform them that they were in the wrong location and provide them with information about how to reach the correct site.

A minority of the learners, newly enrolled students, were not very familiar with the campus and its environment. Therefore, the simple map was not sufficiently helpful, causing them to become disoriented. Given the popularity of navigation systems nowadays, the positioning points indicating the location of the individuals could be incorporated into the MCL system to assist with navigation. If the map indicates these points, it would help learners to identify their locations easily and accurately.

5.5 System functions

For the future enhancement of the MCL system, learners suggested adding the function of instant translations or online vocabulary inquiries. This would be especially helpful for learning in another language and would reduce the burden on learners when operating the system. To further reduce any inconvenience, it is suggested that the future vocabulary page should display words along with related text and definitions; the learners could then navigate between the learning interface and vocabulary page by left–right swiping on the screen of the mobile device.

5.6 Audio guide

The MCL system developed allowed learners to study the plants on site through reading. With increasing wireless Internet speeds, one possibility is to incorporate an audio guide into the system. Instead of reading text, the learners could listen to the English information about the plants, which would simultaneously help them improve their listening skills.

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