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A Study of Campus Butterfly Ecology Learning System based on Augmented Reality and Mobile Learning

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***Abstract*—This study used augmented reality and mobile learning technologies to design a virtual butterfly ecological environment for learning butterfly ecology. Students can breed virtual caterpillars on host plants using smart phones, and become familiar with butterfly's life cycle by observing their growth. The virtual campus butterfly ecological environment can reduce the difficulty of building and managing a real butterfly garden, and solve the problems of insufficient species and amount of butterflies. Providing a context-aware learning environment, the system can enhance students' learning motivation and interest via virtual breeding and observation activities. Thus, it can be used as an assistant tool for learning butterfly ecology in elementary and junior high schools.**

Keywords- augmented reality, mobile learning, smart phone, context awareness, game-based learning

I. INTRODUCTION

An insect's life cycle includes the egg, larva, pupa, and imago (Figure 1), and finally produces offspring before the end of its life. Observing insects' life cycle is an important part of life education, through which one can see how the life cycle continues and gains numerous inspirations [1].

Figure 1. The life cycle of a butterfly

In the ecosystems, butterflies pollinate flowers as they gather nectar, helping plants to reproduce. Thus, they are indispensable in the food chains of ecosystems since caterpillars feed on plants while butterflies serve as the food for predators. Butterflies are beautiful insects with light and graceful bodies. Their dazzling colors and elegant dances instill vigor and vitality into the nature. Large numbers of butterflies, no matter in the wild or captivity, can always attract a lot of visitors and are therefore of great value to tourism and science education.

In recent years, the over-exploitation of mountains has devastated the butterfly habitats, resulting in the decrease of butterfly species and populations. The overuse of pesticide further jeopardized their survival [2].

Suitable natural environments are vital to the survival of butterflies. Many schools cannot provide appropriate living environments for butterflies because they are situated in downtown areas. Thus, only few butterfly species are found on campus. For the purposes of education and recreation, insect museums or butterfly gardens (Figure 2) are built in many countries, which exhibit real butterflies and specimens, to provide multi-media information, and resources for the related researchers.

Figure 2. An artificial butterfly garden in Canada

The topics related to butterflies and insects can often be found in the textbooks of science education in elementary and junior high schools. Therefore, it is a good idea to use green space on campus for attracting butterflies by planting host plants and nectar plants. The ecological environment can be used as an assistant tool for students to increase their knowledge about butterfly and conservation by the breeding and observation activities. The school teachers can also plan and design their campus as a butterfly or ecological garden for educational applications.

The main objective of building a butterfly garden is to simulate an open and natural environment for students to observe butterfly ecology to understand the dependency and interaction between butterflies and their host plants. Since the construction and management of a butterfly garden is not easy, requiring professional planning and maintaining, not many schools own a butterfly garden.

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As the advance of information and communication technologies (ICT), the mobile devices such as personal digital assistant (PDA), smart phone and tablet PC have been applied widely in teaching activities. Consequently, the human's learning is not limited to sitting in classroom, while it can be done anytime and anywhere using any device [3]. In 1970, Schiller and Voidard [4] proposed the concept of context awareness, using the global positioning system (GPS) to obtain a user's position for providing services. The idea is to meet the user's sensational requirement by updating the information to reflect the current position and time according to environmental changes [5].

Recently, augmented reality (AR) is becoming more and more popular. AR emphasizes the combination of virtual reality and the real-world information. By setting the virtual objects at a predefined position in the real world, the users can receive a real and special experience in the integrated environment by interacting with the AR system.

Azuma [6] considered AR a revolution of virtual reality, and its major features are (1) the interaction between real and virtual worlds, (2) in real time, and (3) in the 3D space. As the functions of smart phones become more powerful, a lot of AR software in iPhone and Android System has been developed for various applications.

This study used AR and mobile learning technologies to develop a butterfly ecological learning system, operated in coordination with campus host plants and nectar plants. The system can be used as an assistant tool in science education in elementary and junior high schools. The main objective is to combine real and virtual learning situations to enhance learning interest and motivation. Students can breed virtual caterpillars on the host plants using smart phones, and become familiar with butterfly's life cycle and ecology by observing their growth.

In addition, a virtual green house was designed to provide more butterfly species and insects for observation. In the green house, many kinds of host plants and nectar plants were grew to provide a suitable ecological environment for butterflies. Students can use a virtual telescope to trace the butterflies, and join the game of catching a butterfly to become familiar with different kinds of butterflies.

The system also provides the functions of editing user interface and teaching materials. Teachers can record the GPS coordinates of host plants and nectar plants on campus, create the butterfly database and student accounts, and set up the position and contents of virtual green house.

The campus AR butterfly ecological learning system can solve the problems of building and managing a real butterfly garden as well as insufficient kinds and amount of butterflies in real butterfly gardens. It provides a context-aware learning environment, where students can enhance their learning motivation and interest by virtual feeding and observation activities. Thus, it is a suitable tool for science education in elementary and junior high schools.

The remainder of this paper is organized as following. Section 2 illustrates the methodology for designing the system. Section 3 describes the teaching experiment for analyzing students' learning effectiveness and their attitudes after using the system. Section 4 is the conclusion.

II. SYSTEM DESIGN

In this study, a campus AR butterfly ecological learning system was developed using the built-in functions of smart phones, including multi-media, touch screen, GPS, electric compass, and 3G communication functions, to provide a context-aware learning environment. The system operates together with campus ecological environment where students can feed caterpillars on host plants and observe butterflies on nectar plants. They can also enter the virtual green house to learn more species of butterflies (Figure 3).

Figure 3. The virtual green house on a smart phone

The process for developing the system is described in the following. This study first created 3D butterfly models using computer graphic techniques according to the appearance of butterflies, of which the motions were simulated by the control of state-transition matrixes. In the virtual green house, many kinds of host plants and nectar plants were grew to provide a suitable ecological environment for butterflies and other insects. The design of flowers, trees and insects in the virtual scene is similar to that of butterflies. The texture images for these models were obtained, and then computer graphic techniques were used to create their 3D models. Finally, the texture images were pasted on the surfaces of these models. For the insects such as bees and beetles, their motions were simulated by some other control programs with state-transition matrixes.

This study designed the campus AR butterfly ecological learning system based on the learning unit of "Butterfly's Life Cycle" in nature science for the fourth-grade students in elementary schools. An analysis was conducted to realize the requirement of its learning contents, and then the system was designed based on the course outline and learning objective. Since the theory of situated learning emphasizes the reality of learning activities [6], the instructional design is focused on the connection with daily-life experiences to provide the students with learning activities close to real situations, for example, feeding and observing butterflies.

This study developed the system based on the contents of nature science textbooks related to butterfly ecology, which include the following topics:

- What is an insect?
- How to name an insect?
- The classification of butterflies

- The life cycle of butterflies
- The distribution of butterflies in Taiwan
- Breeding butterflies
- How to distinguish the sex of butterflies?
- Butterfly's natural enemy and defense
- Conservation of butterflies

After analyzing the learning contents and objective, the campus AR butterfly ecological environment was developed by embedding the concepts of situated learning and game-based learning to enhance students' learning interest and motivation. In the following, the design of butterfly models, the ecological environment and the virtual green house is described. Also, the design of user interface and application programs on the smart phone using the functions of GPS and electric compass is described.

A. Butterfly model design

The major part for the system design in this study is the dynamic and stereo visual effects of butterflies and virtual scenes, which can be done by computer graphic techniques [7]. When designing butterfly models, the scanned images of butterflies were obtained by removing the background to produce the outlines and texture materials. Then, the outlines were drawn from different elevations through observation, and the shape of a butterfly was determined by calculating the points along its outlines. Finally, the texture image was pasted to its surface (Figure 4), and the completed model can fly and change directions in the 3D virtual scene under the control of a program.

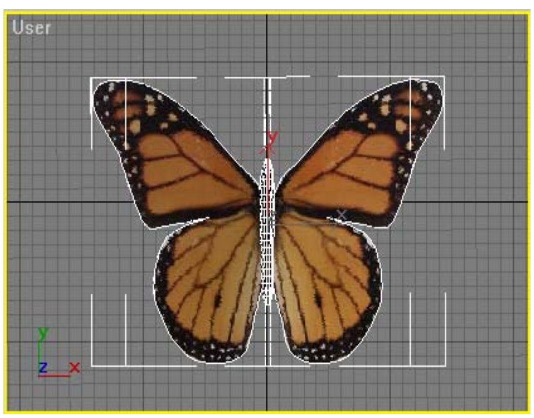

Figure 4. Pasting texture to the butterfly model

To simulate the motion of a butterfly in the virtual 3D space, the model of movement and rotation was created according to the flying motion of butterfly. A state transition diagram was used to imitate the behavior of a butterfly, of which the time intervals for state transition were randomly distributed. After the probabilities of state transition were determined, a Markov model was used to simulate the motion of a butterfly. By using the stochastic models, even the same kind of butterflies (with the same model) would generate different paths in their flying motion. For different kinds of butterflies, the probabilities of state transition were adjusted to imitate different motions (Figure 5).

State transition to simulate the flying motion

B. AR butterfly ecological environment

This study combined the school campus to design an AR butterfly ecological learning system such that students can learn in a familiar environment, making situated cognition more concrete. They can obtain the GPS coordinates of host plants and nectar plants by smart phones and received the features and related learning contents from the database on the server via 3G network (Figure 6).

Figure 5. Accessing the learning contents via 3G network

This study chose an open area in the campus as the place of virtual green house, and set the GPS coordinates at its corners to integrate with the campus environment. Different kinds of butterflies and their host/nectar plants were added to the virtual green house. After completion, the students can see the virtual green house on their smart phones when approaching the area. They can see the virtual caterpillars on the host plants or virtual butterflies flying around the nectar plants on their smart phones (Figure 7).

Figure 6. Observing butterflies on the smart phone

C. Breeding butterflies

To enhance the knowledge about butterfly ecology, the system provides the function of breeding butterflies. Users can breed their own butterflies using the programs on their smart phones (Figure 8) to connect to the database system via 3G network. They have to register for an account and set the password at the beginning, and then select what kind of butterflies to breed. They also need to be familiar with the host plants in order to put the eggs on the host plants.

Figure 7. Breeding butterflies using smart phone

Students can observe the growth of butterflies during the life cycle of egg, larva, pupa, and imago to understand their growing process. Since the breeding program was designed according to the life cycle of butterflies, it can determine the butterfly is currently in which stage and show the proper appearance. For example, after a week, the egg has become a larva and it can eat the leaves. After a few days, the larva has become a pupa, and it finally becomes a butterfly after some more days. Students can record the changes in each stage to become familiar with butterfly's life cycle.

D. GPS and electric compass

In this study, the researchers used smart phone, AR and mobile learning technologies to develop a campus butterfly ecological learning system to provide a situated learning environment for students to study butterfly ecology. The software ShiVa3D was used for the AR design. It is a powerful 3D development platform, and the output can be published on Windows, Mac OS, iPhone, iPad, and Android System. Shiva3D uses LUA Script and WUSWUG editor, and it also supports C/C++ and Java, so its users can develop their own SDK. The 3D models of butterflies and the virtual scene of green house were exported to ShiVa3D for the design of user interface using LUA Script. The system was integrated with the real campus by using GPS, electric compass and overlay display functions on the smart phone to interact with users in the AR environment.

The development platform for the Android application programs on the smart phone is Windows OS installed with JDK, Android 1.5 SDK, Eclipse and Android Development Tool (ADT) Plug-in. This study used the built-in GPS and electric compass functions on the smart phone to acquire the user's current position and orientation. Those data can be botained by the Sensor Event API, which provides two types of data: (1) orientation, including Azimuth, Pitch and Roll, and (2) accelerometer, including the accelerometers in X, Y, and directions minus the gravity (9.81 m/s2). The data can also be used to measure the user's motion. During operation, the smart phone uses its GPS to obtain current position, and then determines if it is close to the learning area to decide whether the smart phone should trigger the breeding or observation activities via the 3G network (Figure 9).

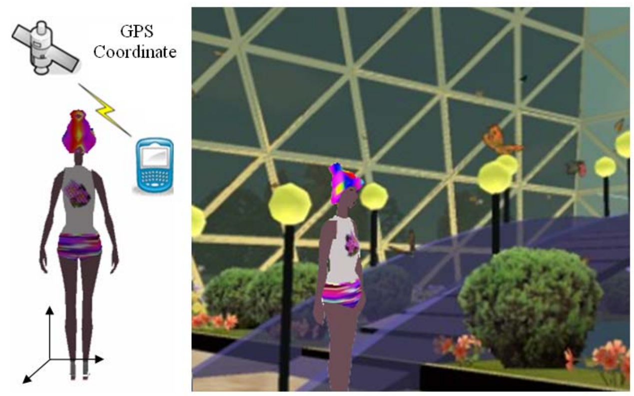

Figure 8. The smart phone using GPS to obtain current position

Students can breed virtual caterpillars using their smart phones and observe the growing process to enhance their understanding about butterfly ecology and life cycle. The breeding programs were written in Java, PHP and MySQL database. When the smart phone is connected to the server via 3G network, the server will transmit the learning contents to PHP engine for further processing. Finally, the data for breeding activities are sent back to the user's smart phone for displaying and online interaction.

III. TEACHING EXPERIMENT

To investigate the learning effectiveness of students after using the AR butterfly ecological learning system, a teaching experiment was conducted in an elementary school at Hsinchu, Taiwan. Two classes (30 students in each class) were randomly selected from the fourth grade, one as the experimental group and the other as the control group. This study used the "nonequivalent groups pretest and posttest" experiment design to analyze if different teaching methods would lead to different learning effectiveness. In this experiment, the independent term was teaching method, the dependent term was students' ability after learning, the covariant term was student's ability before learning, and the control variants were teacher, time, and learning contents. A survey questionnaire was given to the experimental group to analyze their attitudes and opinions after using the system, which could be used for future reference. The categories of the survey questions included: webpage learning contents, user interface, multimedia design, and practicality.

The two groups of students took the pretest a week before the teaching experiment. The teacher spent an hour to demonstrate how to use the smart phone for learning on the campus AR butterfly ecological system. Then, both groups studied the learning unit of "Butterfly's Life Cycle" for six weeks. During this period of time, the experimental group students could use smart phones to breed and observe virtual butterflies after class. Six weeks later, the two groups of students took the posttest to compare whether a significant difference existed in their learning effectiveness.

The test questions include the breeding process, butterfly ecology and life cycle, and outdoor observation. To ensure the reliability and validity, the test questions were designed according to the learning contents, course outline and learning objective of textbooks. Thirty students from another class were asked to take the test to ensure they understood the questions. Also, two science teachers had reviewed and modified the questions to enhance their validity. Finally, 25 questions were selected as the achievement test questions for the usage in the pretest and posttest.

To investigate whether using the campus AR butterfly ecology learning system would cause a significant difference in students' learning effectiveness, this experiment adopted a one-way ANCOVA, where the pretest was the covariant, the posttest was the dependent variant, and the teaching method was the independent term. According to theories of covariant analysis, it was required to exam the regression coefficient within each group to see if they fitted the assumption of statistic equivalence.

The descriptive statistics on the regression coefficient test showed that the two linear regressions have the same slope, which also means the relationship between the covariant term and the dependent term was not affected by the independent term. Hence, it satisfied the hypothesis of statistically equivalent regression coefficient within the control group and experimental group and was qualified for the covariant analysis.

In order to find out the effectiveness of teaching with AR system, this study used a dependent sample t-test to evaluate each group's pretest and posttest scores to see whether there was a significant difference. There were 25 questions in the test, and each correct answer was worth 4 point. According to the results, the experimental group and control group both improved significantly in the achievement test. Therefore, an ANCOVA was conducted further to see if a significant difference existed between these two groups.

The one-way ANCOVA used pretest scores as covariates, teaching method as independent variable, and posttest scores as dependent variable, to perform the statistical analysis. The statistical results showed that the pretest scores had a significant impact on the posttest scores. After removing the influence of covariates, teaching method had a significant impact on the posttest scores ($p = 0.04 < 0.05$), indicating the learning effectiveness of experimental group was better than that of the control group. Therefore, using the AR butterfly ecological learning system can effectively help students improve their learning.

According to the survey results, most students found the AR butterfly ecological learning system easy to use, lively and abundant in contents, interesting, and providing a lot of knowledge related to butterflies, and all these helped them understand butterfly ecology. In addition, the breeding game increased their interest in learning, and left a deep impression about butterfly's life cycle and ecology.

IV. CONCLUSION

Learning by playing is an ideal teaching approach for many educators. The campus AR butterfly ecology learning system developed in this study provides the functions of game-based learning and mobile learning. It combines campus ecological environments to develop a suitable tool for learning ecology and conservation. Students can learn about many species of butterflies through 3G network, and they can also breed virtual butterflies online to acquire more knowledge about their life cycles and host plants.

Compared with real butterfly gardens, the AR butterfly ecological environment is easy to develop and maintain, and it can solve the problem of insufficient species and amount of butterflies. The application of campus AR butterfly ecology learning system is not limited by time or space. Students can learn in their familiar environment, making the situated cognition more concrete. Therefore, it provides an interesting game-based learning environment using AR and mobile learning technologies, and achieves educational purpose via mobile devices and 3G network. It is highly interactive, providing 3D visual effects and interactive user interface. Thus, the system can help understand butterfly species, protect butterfly ecology, and assist natural science education in elementary and secondary schools.

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