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An Augmented-Reality Interactive Card Game for Teaching Elementary School Students

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***Abstract*—**Game-based learning can enhance the learning motivation of students and provide a means for them to learn through playing games. This study used augmented reality technology to develop an interactive card game as a game-based teaching aid for delivering elementary school science course content with the aim of enhancing student learning processes and outcomes. Through playing the proposed card game, students can familiarize themselves with appearance, features, and foraging behaviors of insects. The system records the actions of students, enabling teachers to determine their students' learning progress. In this study, 37 students participated in an assessment experiment and provided feedback through questionnaires. Their responses indicated that they were significantly more motivated to learn after playing the game, and their feedback was mostly positive.

***Keywords*—**Game-based learning, learning motivation, teaching aid, augmented reality.

I. Introduction

RECENTLY, numerous studies have promoted game-based learning because games are more appealing than conventional instructional methods and can increase learners' dedication to their study. Learning through games involves not only cognitive ability but also affective, functional, and social learning abilities. Another major feature of games is that they can generate intrinsic motivation because most game players actively and voluntarily engage in gaming. Among the various types of games, computer games are becoming widely adopted in education because of their considerable potential for improving learning outcomes. According to Carroll [4], computer games are appealing to students because they entail adventures, challenges, and novelty, which evoke curiosity and induce motivation. Therefore, in the context of using computer games as a teaching aid, online games are the most recent development in the field of game-based computer-assisted learning.

To date, instructional materials have mostly been texts or videos that engage students in a one-way process of information absorption without generating a profound impact on them. Consequently, the learning process becomes fragmented and overall comprehension of the content is low. Furthermore, students who learn through conventional methods may easily become mentally fatigued after studying for extended periods, which may seriously reduce their learning outcomes and increase the difficulty of learning. In elementary-school science and life technology courses, teachers mostly give lectures aided by pictures or ecological films when teaching students about animals and plants. However, all of these approaches are characterized by a one-way learning process with set content.

Through adopting interactive gaming as a strategy for promoting learning and enhancing student learning motivation, this study developed an augmented-reality (AR) interactive card game that was inexpensive to implement and free from temporal and spatial constraints.

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II. Literature Review

Dempsey et al. [5] regarded games as rule-based entertainment activity involving at least one player. Furthermore, games inherently incorporate goals, restrictions, challenges, rewards, and outcomes. Overall, games have become an integral part of human life because they provide a sense of satisfaction, joy, and freedom.

Alessi and Trollip [14] argued that games transform learners into active participants through promoting competitive learning. Ellington et al. [2] considered that because students find games interesting, they can maintain their attention for extended periods when used in learning. Teaching with games is unanimously regarded by numerous educational scholars as the optimal teaching method for motivating students to learn.

Intrinsically, games can facilitate the development of characteristics such as patience, initiative, awareness, and flexibility in players, which are beneficial to enhancing primary capabilities (e.g., problem-solving strategies). Extrinsically, games can act as a guide for players, teaching them to become more receptive to suggestions, active in seeking support, willing to cooperate, and interested in their current circumstances and future goals. Such benefits and the affective attitudes that form from successfully applying problem-solving strategies can manifest as crisis management and conflict resolution skills.

Computer games can induce student learning motivation because they are challenging, interesting, and creative. Terrell and Rendulic [12] applied a computer game-based learning approach to develop software for teaching elementary school courses and determined that this approach to learning enhanced student intrinsic motivation and learning outcomes. Moreover, the learning method and process embedded in computer games satisfy the following requirements [10]: (a) providing a

stimulus; (b) directing learner activities; (c) presenting a model for goal achievement; (d) generating extrinsic motivation, (e) directing cognitive development; (f) facilitating knowledge transfer; (g) assessing learning outcomes; and (h) providing feedback. With proper guidance, developing computer game-based learning software can assist both teaching and learning.

Tu [16] indicated that the intrinsic learning motivation involved in computer games for teaching can create satisfactory learning effects:

1) Active learning: Students develop an active attitude toward exploration and experimentation through the process of gameplay.
2) Enhanced learning interest: Games per se are adequately interesting to attract players; when integrated with instructional content, games can make uninteresting course content seem more exciting.
3) Individualized learning experience: Games enable students to learn according to their level of ability and interest; furthermore, teachers can provide various levels of game content for students with different learning abilities.
4) Reduced learning pressure: Students typically find conventional teaching methods to be relatively uninteresting, and homework and exams create stress for students. By contrast, computer game-based learning enables students to learn in a relatively less stressful setting. When a student makes an incorrect decision while playing a game, the only consequence is that their character might be defeated or their game ends; by contrast, when they make the wrong decision in real life, a heavy burden might be imposed on them.
5) Creative thinking and learning: The creativity involved in visualized, experimental, and explorative games process can facilitate learning.
6) Remedial instruction: Students can use learning games outside of regular classes to continue learning, which can improve their academic performance, and enhance their learning motivation.

As an extension of virtual reality (VR) technology, AR technology integrates VR and reality. However, VR is disconnected from daily life because all of the objects in a VR setting are virtual objects; however, AR provides a more informative and interactive experience because it integrates both virtual and real-world objects [15].

Currently, two definitions are commonly used in the literature on AR. Azuma [9] proposed that AR consists of three criteria: (a) integration of the real and the virtual; (b) instantaneous interaction; and (c) a three-dimensional space. Milgram et al.[8] proposed a reality–virtuality continuum that is divided into two modes: real environments are at one end of the continuum, virtual environments are at the other end, and between these extremes is what is referred to as mixed reality, in which AR is nearer to the real environments and VR is nearer to the virtual environments.

Enyedy [7] applied AR technology to teach Newtonian mechanics through an activity in which students played the role of a ball, moving to nearby AR objects to observe and learn a ball's movement path and collision course. Chen [1] proposed a AR system (ARLIS) to enhance the performance of learning in library. For the learners with the field-dependent cognitive style, the learning performance for the AR group is better than commonly group.

Oh and Byun [11] designed a game in which students played as a gardener and were required to take care of the plants in a virtual garden. Gameplay involved using virtual objects representing light and water to tend to the plants in order to learn about the influence of light and water on plant growth. Both of the aforementioned studies were targeted at elementary school students. Therefore, in the present study, an AR-based interactive card game was designed to determine whether the game-based learning approach can be adapted for elementary school learning activities. Lin [3] designed a AR fishing game to teach the concept of fish conservation and habitat. Hsiao [6] proposed an AR game that learners put on read gloves and answer chemistry questions by jumping, boxing and stretching.

III. System Implementation

To create AR, a camera is used to capture video images of an external environment. Subsequently, the images are analyzed to determine whether predefined objects of interest are present in the video footage. After the objects are detected, virtual objects are superimposed over the detected objects for viewing on a display. Subsequently, the position and alignment of a virtual object can be adjusted according to the viewer's relative position to create a sense of reality. In this study, the Vuforia AR library was employed to identify and position the objects to design a card game for students. Fig. 1 is an image of the style of cards used in the game. The cards can be used in a wide range of applications because they can be printed using an ordinary printer without the need to purchase expensive or specialized equipment.

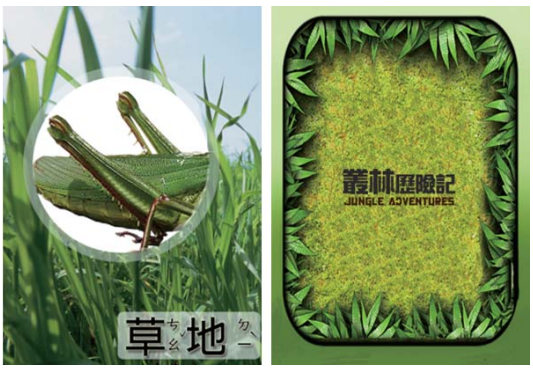

Fig. 1 Answer cards (front and back)

Fig. 2 depicts the procedure of playing the proposed interactive card game. First, a player must prepare a card with specific graphics (referred to hereafter as markers) printed on it. After the an image of the card is captured using a camera, Vuforia is employed to identify the IDs represented by the markers, identify the markers' positions, superimpose the corresponding three-dimensional model onto the marker, and

then display the models and graphics on the screen. The players can then view a combination of the video image and three-dimensional models on the display.

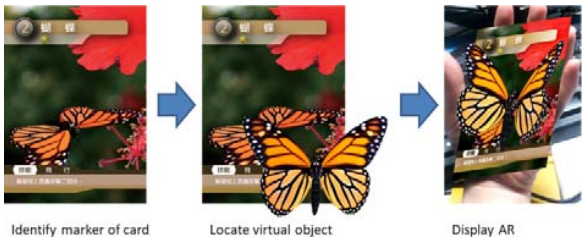

Fig. 2 Procedure of processing an AR interactive game card

This study adopted AR technology to design answer cards in which the markers on the card were used to identify different cards. This technology was applied to a quiz game, in which the system automatically determined whether the correct or incorrect answer cards were presented by the players and then provided feedback accordingly.

The learning themes adopted in this study are as follows:

1) Appearance and features of animals and plants: Students acquire basic knowledge ranging from the appearance and features of animals as well as the names and locations of body parts to discerning the similarities and differences between animals.
2) Animal movement: Students observe the body structures and movements of animals to identify the association between the two based on the similarities to the mechanical principles of movements.
3) Foraging behavior: Using real examples of foraging animals, students analyze the animals' foraging behaviors to understand the association between foraging methods and body structure.

This game was designed to develop learners' ability to observe and understand the physical features of and differences between animals. The game can be divided into two modes of gameplay:

1. Puzzle: Learners were given cards (each representing one animal body part) and task instructions. For example, to complete a task about a mantis, a learner must find the cards representing a mantis's body parts (e.g., head, thorax, and legs) to assemble a mantis. This game was aimed at familiarizing learners with animals' physical features.
2. Quiz: This game revealed the students' learning progress through posing a series of questions. For example, for the question "What is the hunting organ of a mantis," the students had to find the card with the image the forelegs of a mantis. This game was aimed at familiarizing learners with the functions of an insect's body parts.

Fig. 3 presents screen images of the game. In the game, the students played as an explorer on a small island and were required to solve the challenges encountered by the insects there. The challenges were based on the aforementioned learning themes. For example, to help an insect that had lost its foraging organ, the students were required to present the card of the missing foraging organ to a camera and then place the organ in the correct location to complete the task. The puzzle game was utilized to help students observe an insect's physical features and anatomy. Students must position tiles in the correct location to complete each task.

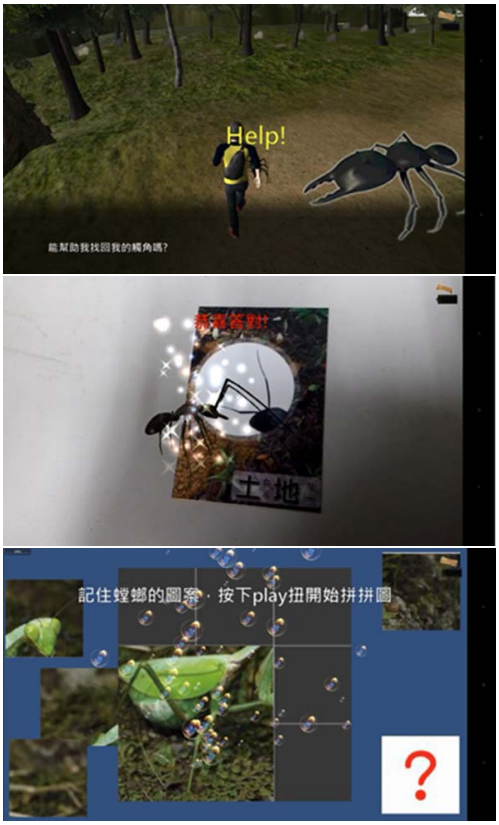

Fig. 3 Puzzle-solving images of the game

The game consisted of five levels and questions on ants, mantes, butterflies, locusts, and bees, and featured games modes comprising a single question, a puzzle, and a task in which several cards were involved. The students' answers were recorded in the insect catalog of the game, and the game was over after all of the insect images were collected and all of the levels were completed.

In summary, the proposed AR interactive card game features the following strengths:

1) The cards can be printed using an ordinary printer and white paper, and the game can be played on an Android-based tablet device. This game is suitable for use in elementary schools because it does not require any special hardware or teaching aid.
2) Gameplay is intuitive because students can answer questions by simply presenting cards.
3) The cards feature three-dimensional models of insects for students to examine their appearance and features. Compared with conventional methods of human–computer interaction, in which a mouse is used to rotate an object, the proposed game is more intuitive and convenient because students are required to simply adjust the position

and alignment of the cards.

IV. Learning Activities

This study was aimed at developing a teaching aid to enhance the learning motivation of students. After teachers give a lecture on course content, students can review the content by playing the game. Furthermore, game-based learning can enhance students' learning motivation and encourage them actively participate in their learning.

An assessment experiment was conducted at an elementary school in Taiwan in December 2014. The participants were fourth-grade (n = 20) and sixth-grade (n = 17) students. Each student was required to complete a pretest of learning motivation 1 week before the experiment. The experiment took 80 min to conduct, and each class was divided into two groups that separately participated in a 40-min test. Before the experiment, the researchers spent 5 min explaining the objectives and rules of the game. Subsequently, the students had 30 min to play the game and solve the problems. Finally, the students spent 5 min answering a posttest questionnaire on their learning motivation and preference, completing the test.

Learning assessment plans are primarily aimed at identifying a student's progress in affective learning. This study adopted the test scale developed in the Construction of Learning Strategies for Students across Grades I [13]. Focusing on elementary school students, the scale adopted in the present study involved affective subscales for measuring students' attention, learning motivation, and anxiety. We adopted this scale to investigate whether the proposed interactive card game positively influenced the students' performance in the affective domain.

The pretest and posttest learning motivation scores were compared using an ANOVA. The results revealed a significant improvement between the pretest and posttest scores, indicating that the students' learning motivation increased considerably after playing the game. These results confirm that the proposed AR interactive card game can enhance elementary school students' learning motivation.

The posttest questionnaire contained 13 items measuring the students' affective learning ability. A 5-point Likert scale with scores ranging from 1 (*strongly disagree*) to 5(*strongly agree*) was employed to examine the user preferences, learning effects, user interface, and game content. Table I shows that most items received a score higher than 4, indicating that the students felt positive about the game. Moreover, the Grade 6 students scored higher than the Grade 4 students did. Among the items, only Items 1, 5, 6, and 8 received a score below 4. These items are discussed and analyzed in the following paragraphs.

Items 1 and 5: The students in Grade 4 lacked diverse experience with learning methods and tended to focus on the task of learning, despite learning being integrated into the game. Therefore, they regarded the game as an aid for teachers to test their learning outcomes and were overly careful when answering the questions in the game. However, both relaxed and prudent learning attitudes yield positive learning outcomes; therefore, neither learning attitude should be the sole focus of the game tasks; instead, a balanced game design should be developed to accommodate both attitudes.

Items 6 and 8: During the experiment, we found that the Grade 4 students experienced difficulty holding the tablet device to take pictures of the cards because their hands would shake, increasing the number of failed attempts to identify the cards. Furthermore, these students could not hold both the tablet device and the cards for a long time, and therefore required the help from teaching assistants, which interrupted their learning pace and focus. This problem can be solved by using a mount to secure the tablet device so that students are required to handle only the cards.

TABLE I
Posttest Questionnaire Items

No.	Questionnaire item	Grade 4 students	Grade 6 students
1	I enjoyed playing the learning game (Jungle Adventures).	3.89	4.35
2	I like the way cards are used in playing Jungle Adventures.	4.25	4.53
3	I would introduce the game, Jungle Adventures, to my classmates.	4.00	4.41
4	Playing Jungle Adventures enabled me to review what I have learned in class.	4.05	4.29
5	When playing Jungle Adventures, I am not worried about answering the questions incorrectly and I want to continue playing the game.	3.70	4.19
6	I stayed focused when playing Jungle Adventures.	3.95	4.24
7	Jungle Adventures contains high-resolution images.	4.00	4.35
8	I can play Jungle Adventures without encountering technical difficulty.	3.90	4.18
9	Jungle Adventures is easy to play and understand.	4.11	4.65
10	I have fun playing Jungle Adventures.	4.25	4.47
11	The game Jungle Adventures matches the course content.	4.10	4.53
12	I want to play Jungle Adventures again in the future.	4.30	4.53
13	I look forward to the next level about insects when playing Jungle Adventures.	4.20	4.65

V. Conclusion and Future Work

By making the learning process more interesting, this study enhanced the students' learning motivation and willingness to participate actively in the learning process through game-based learning. We used an inexpensive card system as a teaching aid in designing the proposed AR interactive card game. The cards not only serve as a tool for answering questions and observing insect anatomy, but, they can also be used directly in classroom instruction to make learning a more interactive experience. In the proposed card game, students and learn about insects (e.g., their appearance, features, movements, and foraging behaviors) by playing as an explorer on a small island who helps insects who are in trouble.

To determine the proposed game would influence students' learning motivation and willingness to learn through gaming, we recruited 37 elementary school students from Grades 4 and 6 and used questionnaires to obtain feedback. An ANOVA test on the pretest and posttest scores revealed a significant improvement in their learning motivation scores, indicating that the proposed AR interactive card game increased their

motivation to learn about insects. In addition, the questionnaire included a section on the students' satisfaction with using the system. The students mostly gave scores higher than 4 (maximum score = 5), indicating a high level of satisfaction with the card game. The satisfaction items with scores below 4 were mainly from the Grade 4 students, who were unfamiliar with operating tablet devices and experienced pressure from thinking that the game was a test. We will conduct further research to improve the game functions and user interface to solve this problem.

In the future, we will continue using AR interactive cards to develop interactive games with richer content for students of various levels and from various grades to enable them to comprehensively learn about insects. Furthermore, AR can be used to track which cards the students select and their approach to playing the game, so that teachers can determine their students' learning progress based on how they present the cards. For example, if two cards are presented to the camera simultaneously, the student presenting them might think that both cards are potential answers to a question. In such a case, the teacher can determine the problems the student encountered and clarify any misconceptions. Therefore, we will also develop a learning diagnostic system to analyze how students handle AR interactive cards to provide a reference for both students and teachers engaged in remedial instruction planning.

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