Construction of a Synchronized Multi-Display Augmented Reality Simulation Module for Learning Tidal Effects

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***Abstract*—In recent years, Augmented Reality (AR) has been widely employed in educational settings. Most instructional ARs developed so far only dubbed a single interactive AR image onto a single object. However, more complicated concept learning may require liking two or more correlated phenomenon. The correlation between the revolution of moon and tidal effects on earth is one of such correlated concepts. In this study, a multi-image instructional AR toolkit was developed that is capable of synchronously illustrating the relation of moon revolution and tidal effects. By rotating the earth-moon physical model, students will be able to view on computer screen the phases of the moon and coordinated tidal effects on earth synchronously. Student's satisfactions on AR operations, screen interfaces, and desire to use the AR toolkit were fare. The results of this study would inspire the development of more innovative AR toolkits for instructional applications.**

Keywords- augmented reality, Synchronized multi-display, tidal effect, phases of moon, e-learning

I. INTRODUCTION

Recently, there has been a trend that educational practitioners employ digital technologies to facilitate a more effective learning process. Advanced digital technologies make possible virtual and mix-reality learning environments. Mixed-reality simulations are known to be helpful for improve the learning effectiveness and learning outcomes for abstract science concepts. Among mixed-reality techniques, Augmented Reality (AR) technology is relatively inexpensive and easy to operate. It has been frequently used as the interface for improving learning in various subject matters, and has been proved to be effective for increasing both learning and teaching effectiveness [1] [2] [3] [4] [5].

An AR system is the combination of the virtual and real world. In addition to visualization, users can interact with virtual objects [6]. When students use an AR system in the classroom, we can observe whether or not students are willing to learn by using this system. Previous researches showed that AR systems have educational values because students enjoyed the interaction with virtual objects which is also effective to improve students' learning performance [7] [8] [9]. Hence, AR systems would become helpful tools for learning.

Yuen, Yaoyuneyong, & Johnson defined that AR has three characteristics: (a) it is the combination of real world and virtual elements, (b) it is interactive in real-time, and (c) it is registered in three dimensions[10]. Thus, AR has some potential to influence instruction and learn knowledge from different fields.

Billinghurst indicated that AR systems are proved to be beneficial in education. For instance, students learn by smooth interactions and the extension of new teaching and learning strategies. Aside from that, students are immersed in dynamic learning contents [11]. Several researches have used AR systems in education, including mathematics, science, language, and medicine.

More AR-facilitate science learning researches have been done in this decade. Recent discussions of instructional applications of AR have gone beyond the effectiveness of the AR per se. A Synthetic work of AR research was done by Bujak, Radu, Catrambone, MacIntyre, Zheng, and Golubski (2013). They reviewed recent research on AR learning. They highlighted the potential benefits and limitations of using AR to deliver learning experiences, by presenting an analysis based on psychological constructs, and by comparing AR applications to physical and virtual manipulative. They concluded that although AR shows great promise for extending the resources used for educating our students, there is much research to be done [12]. Finally they suggested that researchers must more specifically address the usefulness of AR from a psychological perspective.

One important psychological aspect worth further exploration is cognitive load in a learning process. Sweller, Merriënboer, and Paas (1998) elucidated that the cognitive load theory "…is concerned with the development of instructional methods that efficiently use people's limited cognitive processing capacity to stimulate their ability to apply acquired knowledge and skills to new situations (p. 63)" [13]. Kirschner (2002) claimed that cognitive load theory can provide guidelines to assist in the presentationof information in a manner that encourages learner activities that optimize intellectual performance [14].

Research has investigated cognitive load during multimedia learning under the perspective of cognitive load theory or multimedia learning theory (Sweller, 1988 [15]; Mayer, 2001 [16]). Both theories postulate that due to limited working memory capacity, it is important to design learning material carefully in order to avoid a too high

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cognitive load. They both assume an unlimited long-term memory but capacity and duration limited working memory.

Seven cognitive load effects need to be considered while attempting to develop an effective instruction [13]. Among them, split-attention effect and modality effect are especially related to AR-based instructional design. Split-attention effect means that learner's attention is easily being distracted while multiple instructional messages are delivered separately. Therefore, multiple messages are better to be incorporated and displayed together. Modality effect, however, means that multiple modalities, for example, audio and video, may result in a better learning effectiveness then a single channel communication.

II. Purpose of the Study

Most instructional ARs developed so far only dubbed a single interactive AR image onto a single object, this arrangement has restricted students could only learn the correlated scientific concepts one at a time. However, more complicated concept learning may require liking two or more correlated phenomenon. In real situations, a scientific concept usually involves two or more phenomena/regulations that need to be observed. We have previously constructed an AR instructional tool kit that allow students to manipulate the model of Sun-Earth and simultaneously observe the interactive AR images of day/night shifts displayed on computer screen [ ]. Before, in traditionally classrooms, students could only imagine this day/night shift while they are playing with the globe. However, in this AR learning toolkit, only a single concept (day/night shift) is augmented on computer screen. Taking the advantage of recent AR techniques, this study intended to go one step further from our previous research to develop an instructional AR that could simultaneously display multiple interactive images, and these images exhibit correlated concepts. This synchronized multi-image display could help students learn more than one correlated concept simultaneously.

The correlation among the revolution of moon, the phase of the moon, and tidal effects on earth is one of such multiple correlated concepts and was selected as the instructional content for our multi-image AR learning toolkit. By rotating the earth-moon physical model, students will be able to view on computer screen the phases of the moon and coordinated tidal effects on earth synchronously.

After completion of the construction of this AR toolkit, it was implemented in real classroom settings to formatively review its instructional effects. Student's satisfactions on AR operations, screen interfaces, and desire to use the AR toolkit were analyzed by questionnaire surveys and interviews.

III. Arrangements of AR Instruction

This AR instructional module has practical applications in real educational settings. In Taiwan's junior high school, most students learn the concept of spatial and several changes of geographical phenomenon in classroom with traditional lecture. The lack of physical demonstrations and hands-on experience, these spatial concepts seem to be difficult to understand. We believe that it is possible to increase student learning motivations and interests by employing adequate technology-supported tools. From this point of view, the technology of AR seems to be appropriate for designing innovative strategies that help student understanding the spatial concepts. We thus developed an AR toolkit particularly used as the facilitations for understanding the phase of moon and tidal effect

IV. Constuction of the AR Instructional Toolkit

The AR simulation toolkit used for the experiment consists of three components: an earth/moon relation turntable, a computer with screen, and a webcam that captures a birds-eye-view of the turntable. This AR toolkit is able to display an earth-moon relational map, synchronized with an animated phases of moon, and relational tidal effects. The trigger image is the moon on a turntable that simulates the revolution of the moon (Fig. 1). Four images, including the life image directly from the webcam, the phases of moon, the earth-moon relational map, and the tidal effects, are able to synchronously animated on a computer screen. Students are able to turn the moon on the turntable manually, and four images will simultaneously simulate the situations according to the date and time displayed on the top of the screen (Fig. 2).

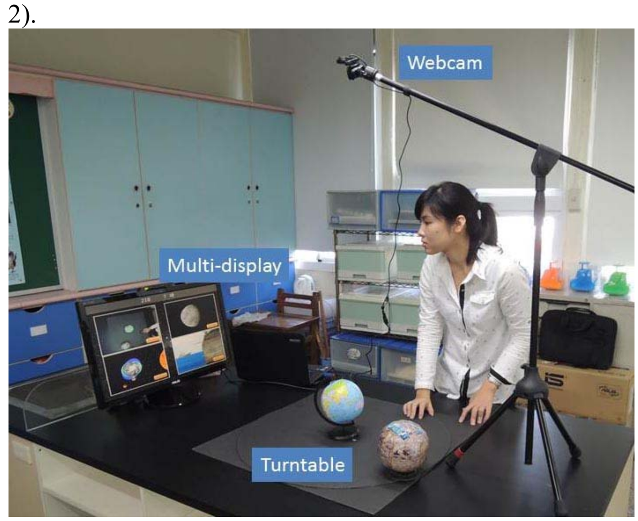

Figure 1. Arrangement of the AR simulation toolkit.

Figure 2. Synchronized multi-display of phase of moon and tidal effect.

The ar instructional toolkit consists of three modules: the image recognition module, the multi-image display module, and the calculation module that calculates the angle of matched image and finds corresponding graphs.

A. *The Image Recognition Module*

A trigger image of the moon is preset and stored on computer. A physical turntable is built with the earth in the center and moon is able to rotate around the earth manually by hands. The surface of moon is graphed and additional makers are tagged so it is recognizable by the AR software. The recognized image is then compared with the trigger image. As the position of the moon varies around its orbit so that its direction angle is also varied. By calculating the direction angle, we are able to find corresponding images to be display on computer screen.

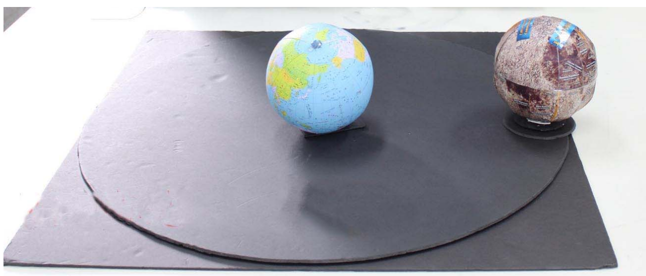

Figure 3. The physical turntable

B. *The multi-image display module*

This module quarters the computer screen. The image on top-left of the screen displays the life image from the shot from the webcam; the image on top-right displays the changes of the phase of moon; the image on the bottom left side is the earth-moon relational map; and the image on the bottom right side is the relational tidal effects.

C. *The Calculation Module*

The moon orbits the earth takes about 29.5 days for each circle. That is, the moon moves 12.2 degrees of direction angle each day. We divided each day into 8 units, 3 hours each. In order to show three natural phenomena that change by time (phases of moon, the revolution of moon, and tidal effects), three set of graphics were prepared to correspond to each time unit for each phenomenon. Lua scripts were written so the AR software is able to detect the moves of the moon on the turntable, calculate its degree of direction angle, find corresponding graph from each set. Therefore, once the learners move the turntable, the three phenomena is synchronously display on the computer screen. Please refer to Figure 4 for better understanding of the textual description.

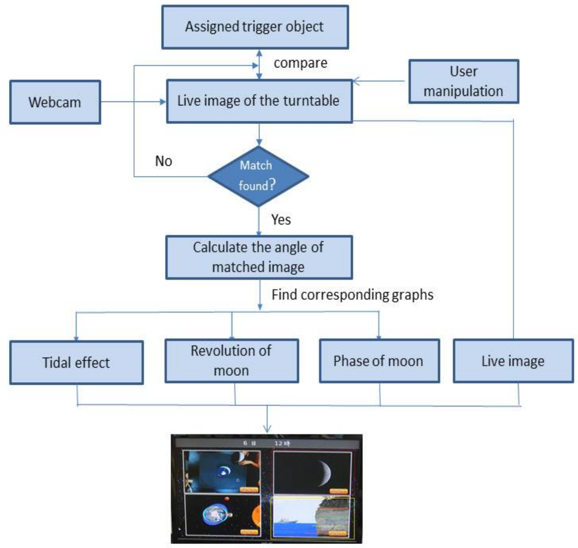

Figure 4. System Operation Flowchart

V. IMPLEMENTATION

After completion of the AR toolkit development, a pilot test was done to gather user information for necessary modification. 24 potential learners were selected and suggestions were made. Minor adjustments of the systems were done to increase the accuracy of image recognition.

This AR toolkit was implemented in classrooms at a junior high school. Totally 58 5th grade students from 3 separate classes were attended. They were divided into groups. Each group consisted of 4 to 5 students. The instructional content is the relationship between phases of moon and tidal effects. Guidance was provided and students learn instructional content by manipulating the AR toolkit after a brief lecture. A questionnaire regarding learning satisfaction was given to formatively evaluate the usefulness of the system. Figure 5 shows a real scene of classroom implementation.

Figure 5. Classroom implementation

VI. Formative Evaluation

A questionnaire was given to all students attended the implementation process. Factors inquired include satisfactions on the ease of use, satisfactions on user interface, and acceptance of the AR instruction. 5-point Likert scale was used. The results indicated that for the ease of use, 83.31% of the participants highly agreed or agreed (hereinafter referred to as agreed) that the AR toolkit is easy to operate; 72.14% of the participants agreed that AR system ran smoothly; and 83.31% of the participants agreed that this toolkit provided sufficient interactions. For the user interface, 78.71% of the participants agreed that synchronized multi-image display facilitated learning correlated concepts; and 82.76% of participants agreed that user interface is simple and clear. For the acceptance of the AR instruction, 82.76% of the participants agreed that the AR instruction helped better learn correlated concepts; 86.20% of the participants agreed that AR instruction is interesting; and 74.57% of the participants agreed that they would like to be taught by AR instruction again.

VII. Conclusion

As the fast development of interactive technologies, AR has wildly used for facilitating science concepts learning. This study intended to develop an AR instructional system that is able to synchronously display multiple images that correlated to corresponding concepts. Three modules are included in the system- the image recognition module, the multi-image display module, and the calculation module. The correlated concepts of phases of moon and tidal effects are embedded as the instructional content. The system is fully developed and implemented. The results of the questionnaire survey indicated that users generally satisfied with the system in terms of the ease of use and the user interface. The users also exhibited the willingness to be taught by AR instruction again.

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