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Augmented reality in the higher education: Students' science concept learning and academic achievement in astronomy

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Abstract

The purpose of this study was to examine the effect of providing learners with diverse approach of simulation-based instructional design, 2D animation (2D), 3D simulation (3D), and augmented reality (AR) on students' moon phases concept learning and their academic achievement. There were 104 senior college students participated in this study. Based on ANOVA analysis, the result showed that: (a) all of the three approaches could enhance learners' performance on academic achievement, however, there were no significant difference between them; (b) students in AR approach outperformed the other two instructional design on moon phases concept learning; (c) students in 3D and AR approach demonstrate higher motivation and concentrate their attention on the learning tasks. This study provided insights for better understanding the design, theory and practice of e-learning through augmented reality technology.

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Keyword: augmented reality; moon phases; concept learning; instructional design; empirical research

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1. Introduction

With the continuous evolution of simulation-based instructional models, it has become possible for education researchers to introduce proper e-learning systems to enhance those learning tasks for which subject attribute and traditional models are ineffective (Yeh, 2004; Guo, 2007). Integrating the advantages of the authentic technologies to provide solutions unlimited by the real environment can resolve problems caused by the following circumstances: the concepts of some subjects may be excessively abstract; some subjects require dangerous experiments and operations; a certain subject may require long periods of time for recording and observation; the surroundings for observation cannot be easily constructed or meet the necessary requirements due to cost and technological limits or remote locations. Researches on simulation-based learning indicate that teaching aided by the operation of interactive 2D or 3D models can significantly help learners to understand spatial concepts (Shelton & Hedley, 2002). In addition, research into using augmented reality (AR) technologies to develop instructional materials desired by teachers and students have confirmed that AR materials can effectively enhance the academic motivation of learners and help them obtain better learning effects (Chen, Wu, & Zhung, 2006). Therefore, simulation-based e-learning system may help learners to obtain more diversified and abundant knowledge in order to construct a complete and correct conceptual framework (Hsu, 2008).

Nowadays, it has become a trend to utilize the characteristics of multimedia and computer aided instruction models for scientific concepts. Through research into the application of 3D animation and the teaching of the moon phases, Ma (2008) discovered that 3D animation instruction improved learners' immediate learning effects on the concepts of moon phases, but that it had no significant difference to the learning outcomes in delayed posttest. Moreover, Li (2010) adopted "Interactive Software of Lunar Phase" to conduct e-learning, proving that multimedia courseware had a significant improvement on the learning effects of concepts, such as the phenomena, causes and periods of the moon phases, as well as the motions of the earth, the sun and the moon. In addition, the learners' misconceptions of the moon phases can be clarified through the presentation of the multimedia. All the above researches came to the same conclusion; by providing teaching materials, such as 2D and 3D animation, a simulation-based e-learning model is really helpful for improving the learning effectiveness of the concepts of the moon phases. However, more evaluations are still required to confirm whether other more authentic presentation modes, such as AR materials, can improve the learning effectiveness of abstract conceptual knowledge, such as the changes and periods of the moon phases.

This research aims to apply AR technology to develop a simulation-based concept learning system on the phases of the moon, as well as discuss the influence of different simulation-based instructional models on the academic achievement in astronomy. It hopes to lay a foundation for further researches into the application of AR on the concepts learning in the natural science field.

2. Augmented reality

AR has been widely applied in many aspects, including medicine, entertainment, education and interactive action guides. This study will integrate AR's application to nature and earth science, and is as follows:

With the Nine Planets system and Garden Learning system as the research content, the researches of Liu, Cheok, Mei-Ling and Theng (2007) helped to develop instructional materials using AR. According to their research, an AR instructional model can give a full demonstration of 3D virtual objects, which is a great advantage compared to narrative or static image-text types. The research results also indicated that this kind of instructional model can effectively improve learners' attention and learning outcomes. Shelton and Hedley (2002) compared the AR model of the Nine Planets with the traditional simulation material (including on-line 2D picture displays and 2D animation), and pointed out that AR model can save time spent by learners on practice and can also reduce the cost of materials designed. Moreover, learning with AR assisted technology, can provide learners with perceptual feedback and interaction, allowing them to understand the content better and reach the learning objectives more easily and less practice through actual interaction with the system (Milgram, Takemunra, Utsumi, and Kishino, 1994).

Billinghurst (2003) holds that the development of AR material supplies a unique education application model in which learners can interact freely with virtual objects in a real environment and acquire new knowledge that is not so easily imitated in a real environment. Kikuo and Tomotsugu (2005) consider that AR is a new pattern applied in teaching and has great potential for future development. This new and unique instructional method and strategy can help learners with little computing experience to interact easily. In addition, different from traditional learning content that only provides static texts and pictures, AR instructional model can lead learners directly to the essence of the learning content.

Eric, Mark, Graham and Barbara (2004) integrated five examples of AR teaching in their research to illustrate the advantages of AR teaching. These advantages include: (1) learners like this kind of instructional material; (2) as far as the courses about spatial concept relations are concerned, AR materials can help learners to clarify relative conceptions; (3) AR materials can better demonstrate knowledge about time concepts than traditional teaching materials; (4) virtual objects produced by the AR learning system are presented as 3D objects and learners can interact directly with these virtual objects; and (5) referring to the concept of constructivism, AR model can allow learners to change their native knowledge, independently.

In accordance with the above researches, applying AR to education has the following advantages:

- Novelty towards learning: AR learning uses new multimedia technology and presents diversified multimedia content through the system, which allows learners to acquire knowledge of concepts and increases their interest in learning. Aided by simulation-based materials, AR combines virtuality and reality to improve the interaction level, stimulating the learners' learning motivation and enthusiasm.
- Interaction with learners: With regards to relatively difficult abstract concepts, learners can practice repeatedly through the interactive operation process. This model can deliver the correct knowledge of concepts to the users. Even learners with little computing experience can improve their comprehension abilities and familiarity through this model.
- Establishment of spatial concepts: If the instructional material can make abstract spatial concepts visible and visualized, it will be of great benefit to learners in terms of promoting learners' understanding towards the spatial concept. AR materials are developed with the possibility of turning abstract to concrete and, thus, they can improve learners' learning effectiveness of spatial concepts.
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Referring to the above three advantages which are about the AR's applications in teaching aspects, the content design of the instructional materials should be in accordance with the learning objectives and concepts that teachers wish to convey to their learners. The development of simulation-based materials should meet the requirements necessary to initiate the different experiences, sensorial stimulation or interaction of learners and even help them to visualize abstract concepts. It is expected that AR materials will help learners to establish correct scientific concepts.

3. Research method

This study aimed to discuss the influence of simulation-based materials on the learning effectiveness of the learning unit on the phases of the moon. Quasi-experimental research was adopted to replicate the students' learning effects in this study. In addition, through T tests on independent samples, this study obtained statistics for the effectiveness of different instructional design for the learning unit between learners using 2D animation materials (2D), 3D simulation materials (3D), and augmented reality materials (AR).

3.1. Simulation-based moon phases Materials

The 2D animation materials on moon phases used in this study were taken from the interactive animation software system on moon phases designed by Wang (2006) through Flash technology, has proven itself was a effectively 2D animation learning system. The 3D simulation system of moon phases was flowered from Google Earth. Tilting the image and flying through the moon in Google Earth suddenly makes the structure and relationships obvious to students. The moon's color stripes and zigzags become more lively and authentic before their eyes. All of these content and materials contains the learning objectives of the learning unit. The system overviews were shown in Fig 1.

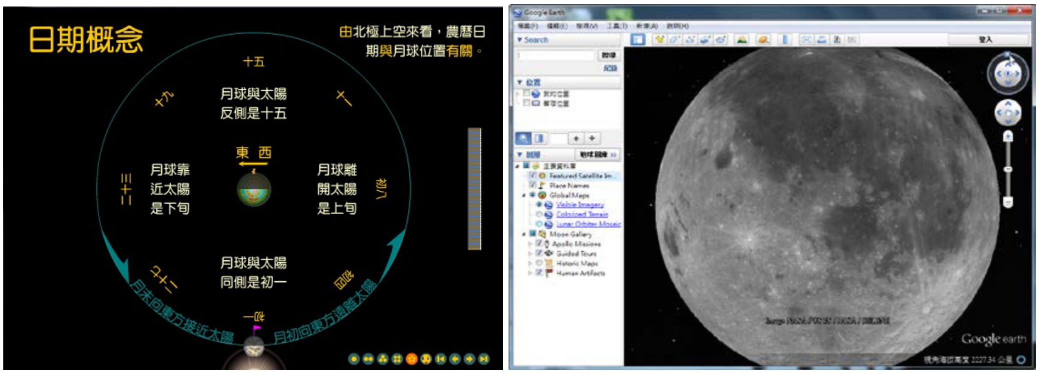

Fig. 1: (Left) The 2D animation materials; (right) The 3D simulation materials

Meanwhile, this study developed its own AR materials using virtual reality technology based on the Total Immersion D'Fusion AR software package, 3D molding software Maya and 2D image processing software Photoshop. The process of material development is shown in Fig 2.

Fig. 2. The construction process of the Augmented Reality Materials of this study

First, the 3D model was imported into D'Fusion AR using molding software Maya. Second, the D'Fusion CV was used to set the graphic cards' pattern, named AR tag, for camera identified. Then, 2D surface materials and system pictures were drawn and design by using Photoshop. Next, we using the D' Fusion AR package to process the above completed model, graphic cards and interfaces with the interactive program language Lua Scipt for advanced interactive. Finally, the design for interaction and the setting of functional dimensions was completed and then upload all files to the learning system website. The system overviews were shown in Fig 3.

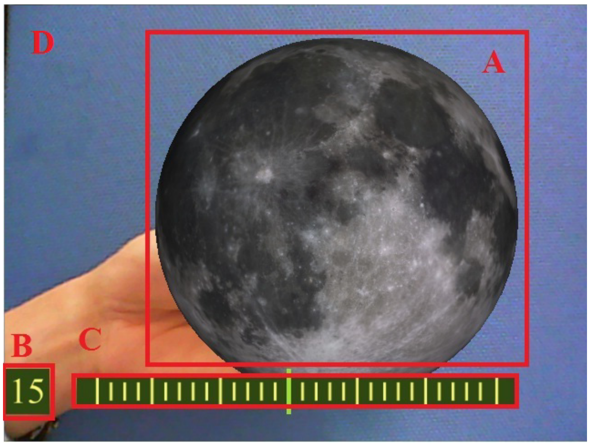

Fig. 3: (A) show 3D object; (B) show lunar calendar date; (C) each day of the month; (D) real world scenarios

It should be noted that the image resolution level of pictures influences the sense of reality of the 3D virtual objects displayed. Additionally, the charting of the adjustments in the moon's shadow area should be in accordance with the real shape of the moon.

3.2. Participants and Scenario

The present study investigated the effect of providing learners with diverse approach of simulation-based instructional model, 2D animation (2D), 3D simulation (3D), and augmented reality (AR) on students' moon phases concept learning and their academic achievement. The participants were 104 juniors students from an education college at a university in the north of Taiwan, including 41 male (39.42%) and 63 female (60.58%), enrolled in two selective course on "computer animation and applications." The samples were divided into three groups and randomly assigned to experimental conditions (AR group) and control group (2D animation and 3D simulation). Base on the simulation-based instructional design, the experimental group and control group adopted exactly the same procedures but different assistant materials. The experimental group (AR group) carried out the unit activities on moon phases with our AR materials. Meanwhile, the control group (2D and 3D group) conducted activities using 2D animation and 3D simulation materials. The research framework is shown in Fig 1.

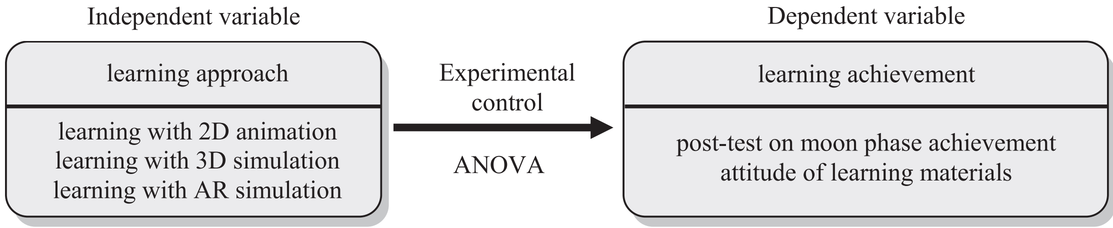

Fig. 4. The research framework of this study

Firstly, the study ran a homogeneity of variance on the students' concepts of the moon phases among three group. Then, the research experiment adopted difference approaches of computer simulation materials to learn related concepts of the moon phases. The primary data collected for this study consisted of: (1) self-report collected from learners, in which after completing each stage of the experiment, they were asked to describe in 30 words the learning task and; (2) weekly interviews recorded by the instructor in class meetings throughout the course; and (3) attitude questionnaire of learning materials; and (4) an online post-test achievement test on moon phase was conducted to examine participants' progress.

3.3. Two-stage questionnaire on the elementary school students concepts of the moon

This study applied two-stage questionnaires on the students' concepts of the moon, as designed by Lai (2002). It aimed to assess the learners' learning degree of the four major concepts in the unit on moon phases, including the phenomena, causes and periods of the moon phases, as well as the motions of the earth, the sun and the moon. It also aimed to analyze the changes in the learners' misconceptions from before the study and after the study. In order to clarify if the notions in the learners' minds were correct scientific concepts, this test applied the two-stage answer method. Two tests were done, specifically a pre-test and a post-test. The test-retest reliability method was applied and the related coefficients of all questions were significantly correlated ($0.41 \leqq r \leqq 0.78$), indicating a good test-retest reliability. The index of internal consistency (α) was 0.64, representing the acceptance level of test reliability. As for the validity, this test adopted content validity. Three professors from the Nature Department and two primary schools teachers were invited to examine the test content in order to construct the content validity of the test. There were a total of 16 test items. Each item of single choice included two parts, option and reason. Two scores were given if both the option and reason were right; otherwise, no score was given. The total score was 32.

Fig. 5. The learning scenario of research implementation

4. Research results and discussion

4.1. Different learning approach of concept learning effects was not significant

The Analysis of Variance (ANOVA) was conducted to examine the main effects of the different learning approach on the dependent measures. Significance level was .05 for data analysis. The descriptive statistics and summary of learning achievement are shown in Table 1. The achievement mean score of all three group indicated that the participants obtained positive progress toward the simulation-based learning. The mean score of the AR group (12.76) was slightly higher than that of the 2D animation group (12.63) and 3D simulation group (11.58). The effects of different treatment on participants' achievement were further analyzed by means of ANOVA.

Table 1. Descriptive statistics and summary of learning achievement in different approach

Learning Approach	N	*Learning Achievement*			
		Pre-test		Post-test	
		M	SD	M	SD
2D animation	36	7.95	3.28	12.63	3.77
3D simulation	35	7.92	3.23	11.58	3.45
AR simulation	33	8.03	3.39	12.76	3.91

First, the Levene's test of equality was conducted on participants' pre-test score of achievement toward simulation-based learning. The result was not significant (F(3, 101) =.312, p =.817). The homogeneity assumption that the error variance of the dependent variable is equal across groups was sustained. Then, the ANOVA summary of different simulation materials for the independent measures of participants' post-test score of achievement is shown in Table 2. The main effect of the ANOVA result was not significant (F(3, 101) = 1.085, p=.216).

Table 2. Summary of the ANOVA result

Source	Type III Sum of Squares	Df	Mean Square	F	*p*
Learning Approach	1478.649	2	359.550	1.085	.216
Error	32561.587	101	102.303		

*p<.05

4.2. Students in 3D and AR approach demonstrate higher motivation

Furthermore, an ANOVA was conducted to examine the main effects of the different learning approach on the learners' attitudes toward the simulation-based learning materials are shown in Table 3. The significance level was also .05 for data analysis.

Table 3: Summary of learners' attitudes on different learning approach

Attitudes	N	Descriptive Statistics		*F*	*p*
		M	SD		
2D animation	36	3.513	.510	3.212	<.01
3D simulation	35	4.509	.608		
AR simulation	33	4.775	.542		

The results showed that some striking effects of difference treatment on learners' attitudes toward simulation-based learning. The effects of different learning approach on the learners' attitudes were very significant (F=3.212, p<.01). Further check by the mean values found the AR simulation group (M=4.775) and 3D simulation group (M=4.509) scored higher than the 2D animation group (M=3.513). The data indicated that the learners perceived more authentic and more realistic outperformed the plain significantly while learning in the learning system with the mechanism of simulation-based design. The result was similar to the researches of Wu, Lee, Chang, and Liang (2013) and Yen, Lee, and Chen(2013). It is interesting and seems worthy to pay more attention on how simulation-based learning design could result in this outcome.

5. Conclusion

This study aimed to discuss the influence of different learning approach (2D animation, 3D simulation and AR materials) on the learning effectiveness of the concepts of moon phases and to analyze the learners' experiences when using AR teaching materials. Owing to this study was a pilot study, the teaching content of which chose only a few concepts related to moon phases as the operating variables. Therefore, the influence of learners' concepts and learning effectiveness other than changes of the moon phases cannot be predicted. Two experimental lessons of 70 minutes were given during this study. According to the data collected from the pre-test and post-test, the following conclusions were obtained.

Firstly, in terms of the influence of different approach of instructional design on the learning effectiveness of the concepts of moon phases, 2D animation, 3D simulation and AR simulation are all helpful for the improvement in learning. However, the differences among the three groups did not reach a significant level. It means that the AR materials on moon phases, as developed by this study, can improve learning effectiveness, but the advantages of AR materials require further exploration. A suggestion for future researchers is to fully understand and authentically display the knowledge content when producing AR materials. More importantly, a complete interactive operation mode that can improve the students' learning interests should be provided.

Otherwise, according to the observations and records of the learning experiences, learners in the 3D and AR simulation group had higher motivation levels and degree of concentration. This study deduces that the reason may be that these materials can provide a more intuitive interactive mode and present abstract concepts more authentically. Therefore, using AR materials can rise the students' learning motivation levels and their degree of concentration. We suggests that future researchers of AR materials explore these aspects further.

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