Using the Augmented Reality for Convex Imaging Experiment

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Abstract: *Augmented Reality (AR) provides new possibilities in simulating teaching environments, experiencing teaching processes, demonstrating teaching results and promoting teaching interaction, due to certain characteristics. This paper introduces the specified case which adopted the convex lens image-forming experiment as material and conducted an interactive and integrated image-forming experiment using AR technology to improve teaching. The case study was mainly to investigate learning attitudes of experimental group students by using AR instructional applications and compare the difference of eighth graders' learning achievements on convex lens image-forming experiment in two learning environments. The results revealed that mean scores indicated by the experimental group increased greater than those indicated by the control group; however there appeared no significant difference between the two groups in post-tests. To sum up, the results show that this learning environment which blends reality with virtuality will greatly stimulate students' learning interests and promote their level of activity, suggesting significant potential in its application in practice.*

Keywords: Virtual reality; Physics education; Innovative instruction

1.Introduction

At present, the applications of AR are mainly divided into two types. One is based on image recognition. Cameras first detect objects or specially designed markers in the real world, which is followed by image processing and analysis, then projects 2D or 3D information on these objects or markers in real time. The other is based on sensors. In this case, it is not necessary to detect specific objects to justify the position where virtual information is presented. Instead, GPS (Global Positioning System) and other sensors (such as gravity accelerators and compass, etc) are used to conduct an overall analysis; then corresponding data is demonstrated on the current scene. We will focus on the first type of AR in this study.

The significance of AR to education rests with providing a self-oriented exploring space for learners under the interaction mode closest to real life, which is especially inspiring and helpful in abstract knowledge. AR aims at improving users' performance and promoting their perception of the world. Models in AR environment can be quickly constructed, operated and rotated. An ideal AR system can integrate users into virtual information seamlessly and enable users to have real-time interactions with 3D objects in the virtual world through the most natural operations, which makes it possible for users to observe objects in the real world inaccessible to human beings or in the micro world which only exist in our imagination from every conceivable angle to explore the essence and principles of the world.

Nowadays, studies about AR have shifted from the algorithm itself to its application in specific fields. Some scholars have made some attempts in education context. Billinghurst, Kato and Pouprev (2001) designed an interface called Magic Book based on AR technology. Contents in the book are converted into animations, which are superimposed on the book in return. Kaufmann and Schmalstieg (2003) envisioned cooperative teacher-student interaction with AR technology and confirmed through his experiments that observing 3D objects in their textbooks and interacting with them is helpful for students to improve spatial abilities. Dünser and Horneker (2007) took fables as materials, added with 3D roles, sounds and interactive tools, to observe how children aged between 5 and 7 communicate and cooperate in learning in an AR-based learning environment. Children use AR tools with signs on them to read stories and complete the tasks. It indicated in the experiment that children had a higher level of concentration in an AR-based learning environment, and they were more willing to make attempts in fulfilling the tasks. Lee and Lee (2008) designed a mathematical game for students in kindergarten and primary school, aiming to help them with the operation of addition. Children will easily get tired of traditional board games. Researchers from Vienna University of Technology presented an AR application in mechanics education (Kaufmann & Meyer, 2008). It utilizes a recent physics engine developed for the PC gaming market to simulate physics experiments on mechanics in real life. Students are able to build their own experiments actively and study them in a three-dimensional virtual world. Priestnall (2009) illustrated a methodology of implementing AR in education. It utilizes aerial photography, Digital Surface Model (DSM) and geology data for three-dimensional contouring, retreating the glacial history of the region. El Sayed, Zayed, and Sharawy (2011) designed an application of AR in education, AR Student Card (ARSC), and examined the learning outcomes with both online and offline solutions. Their research suggests that ARSC will cut down education cost without degrading outcomes. The New Media Consortium (NMC) listed AR as one of the six most potential emerging technologies and practices in its Horizon Report for both 2010 and 2011, predicting that it is likely to enter mainstream use on campuses within 2-3 years (NMC, 2010; NMC, 2011).

This paper introduces the specified case which adopted the convex lens image-forming experiment as material and conducted an interactive and integrated image-forming experiment using AR technology to improve teaching. The study was mainly to investigate learning attitudes of experimental group students by using AR instructional applications and compare the difference of eighth graders' learning achievements on convex lens image-forming experiment in two learning environments.

2.Material and methods

2.1. AR system

Real scene captured on camera is displayed as the bottom layer by the system. According to the calibration parameters of internal and external camera as well as the real three-dimensional position of particular sign created with three-dimensional algorithm in advance in authentic space, the system can figure out the virtual three-dimensional model from the model library. Then, the camera projection matrix of the model would be projected onto the plane of the camera on the marked three-dimensional position. In the end**,** the system synthesizes the image of virtual three-dimensional model on the projection plane and the real space image on the projection plane to export the compound picture combined with virtual reality and actual reality.

2.2.A case study: convex lens instruction

2.2.1. Instructional analysis

After interviewing with some middle school science teachers, we found the convex lens image-forming experiment is a complicated learning unit to junior high school students. Science teachers proposed four instructional problems as follows: Students (1) Are not able to understand the basic physics concepts such as object distance, image distance and focal distance in physics classes. (2)Do not understand some vague concepts including nature of the image-forming, the relationship between the object distance and image distance. (3) Cannot analyze abstract concepts and dynamic problems, such as what will happen as you move the object closer to the lens from far away (4) Cannot fully understand the significance of the experiment and always fail to operate image-forming experiments. To overcome these learning obstacles, researchers try to use AR teaching tools on convex lens image-forming experiment.

2.2.2.Participates

Two classes of eight-grade students from Nankai Foreign Language Middle School in Tianjin City, China, participated in this study. The experimental group consists of 24 students (female, 16; male, 8), using AR tools as a supplemental instructional activity; the control group consists of 26 students (female, 14; male, 12), proceeding with their traditional instruction. The two classes' selection process was based on students' previous academic achievements. The two classes were selected equally to some degree.

2.2.3. AR tool application

Convex imaging augmented reality teaching aids can directly simulate convex imaging experiment, by using three different markers to substitute candle, convex and fluorescent screen respectively. 3D model of convex, and a straight line parallel to the axis which is used to mark focal length and twice focal length, will be displayed on the screen when the camera captured the convex marker. By putting the candle marker and the screen marker on each side of the convex marker respectively, the screen will automatically present relevant objective image based on the position of the distance from candle to convex, as shown in Fig. 1. If the distance between candle and convex is adjusted, the image on screen is also changed correspondently according to the convex imaging rule.

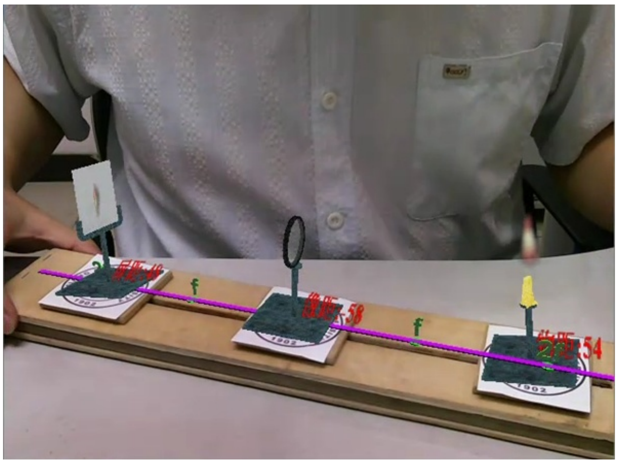

Fig. 1. AR simulation convex imaging experiment.

Assuming object distance is u, image distance is v, and focal length is f. When $u<f$, according to the formula of convex imaging $\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$, virtual image will be seen.

After the teacher displays and instructs students how to use AR tools, students from the experimental group have to practice and learn theses concepts of convex imaging with AR. On the other hand, students from the control group learn with traditional instructional method. Fig. 2 shows students enhancing accomplishing convex imaging experiment.

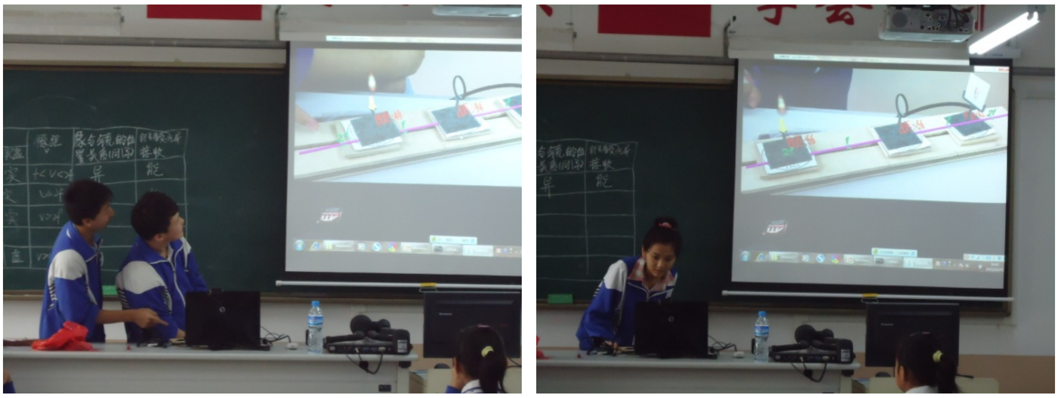

Fig. 2. Students enhancing accomplish convex imaging experiments.

2.2.4. Research design

This study incorporated a quasi-experimental design consisting of a questionnaire survey in order to collect learning achievements of convex lens image-forming experiment and students' learning attitudes towards using AR tools. This study followed a pre-post test with an additional post-test quantitative measure in the experimental group. The research aims of this study are as follows: (1) To compare physics learning achievement between the experimental and control groups. (2) To explore students' feelings about the AR tools learning after they experienced it.

2.2.5. Instruments and analysis

We took two types of instruments in this case study, including learning achievement instrument and AR learning attitudes questionnaire. The learning achievement instrument was a paper and pencil test which was related to images formed by convex lens. The instrument had been examined and revised by science experts, middle science teachers, and instructional designers. The assessment content related to each instructional objective was selected for the instrument. Each student from the control group and experimental group completed a pre-post test on the learning achievement instrument. Results were analyzed through descriptive statistics, independent t-test, in order to compare mean scores of pre-post experimental tests. In addition, students from the experimental group were asked to fill out the questionnaire at the end of the unit of instruction. The questionnaire mainly explored students' learning attitudes towards the AR instructional activities. The questionnaire consists of the students' attitudes towards physics in both In-class learning experiences and AR tools instructional application. Content validity of the attitude instrument was developed by a faculty from Beijing Normal University who had educational technology expertise in the development of attitude instruments. The questionnaire utilized a 5-point Likert scale ranging from the level of ‘‘strongly agree’’ to ‘‘strongly disagree.’’ The instrument had a coefficient of internal consistency (Cronbach's Alpha) of .94. Statistical analysis was conducted using SPSS software.

3.Findings and discussion

3.1.Students' learning achievements

The main purpose of this case study was to explore eighth graders' learning achievements and learning attitudes towards the convex lens experiment with AR instructional applications. The study employed SPSS to analyze both groups' learning achievement scores. The means and standard deviations in pre-tests and post-tests of learning evaluation for both experimental and control group are presented in Table 1. The results revealed that the mean score indicated by the experimental group (M=80.42) increased more than that indicated by the control group (M=78.69) in post-test. In order to know whether or not there is a significant difference between experimental and control group in the post-test scores, independent t-tests was conducted (see Table 2). Although the post-test scores of experimental group were higher than those of control group, the pre-post tests for both groups have also demonstrated that the treatment in the experimental group was not significantly different from that in the control group.

Table 1.Students' pre- and post-test scores in the experimental and control group.

Group		**Pre-test**		**Post-test**	
	N	**Mean**	**SD**	**Mean**	**SD**
Experimental	**24**	67.42	19.19	80.42	15.46
Control	**26**	67.65	15.84	78.69	13.94

Table 2. Independent t-tests.

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	Sig.	T	df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
score	Equal variances assumed	1.768	.233	.415	48	.680	1.72436	4.15691	-6.63368	10.08239
	Equal variances not assumed			.413	46.420	.681	1.72436	4.17448	-6.67638	10.12510

Table 3. Survey results of students' learning attitudes (N=24).

Factors	**Questions**	**Mean**	SD
Physics In-Class Learning Experiences	1. I fear to take physics courses.	4.43	.94
	2. When I' m in a physics course, I always look forward to the end of the course.	4.37	.93
	3. I am interested in some physics phenomena in our daily life and I hope to make inquiries.	4.50	.86
	4. I like to do physics experiments.	4.63	.72
	5. It' s easy to summarize the results of physics experiments.	3.87	.97
AR tool instructional applications	6. AR instructional applications in physics courses attract my attention and stimulate my curiosity, and I want to explore more deeply into physics.	4.47	.82
	7. AR instructional applications are very difficult to understand and are not easy to operate.	3.83	.95
	8. I can fully comprehend the meaning of AR instructional experiments.	4.00	.98
	9. I concentrate in doing experiments when I use AR instructional tools.	4.20	1.06
	10. AR instructional methods facilitate my understanding of physics	4.23	1.07

phenomena and concepts.		
11. The AR instructional method could promote my learning motivation for the physics course.	4.27	.87
12. I extremely prefer learning physics by AR instructional tools.	4.40	.86
13. I am very impressed with AR instructional display and experiments.	4.27	1.01
14. AR instructional tools can help me memorize the results of physics experiments.	4.30	1.02
15. AR instructional method has helped me to link knowledge with physics experiments.	4.13	1.01

3.2.The result of students' learning attitudes

The researchers analyzed the questionnaire questions by dividing them into two main parts: (1) In-class physics learning experiences, and (2) AR tool instructional applications. The results of each part are delivered in Table 3 and the findings are as follows. Experimental group students completed and returned the surveys with Likert 5-point scale questions designed to assess students' learning attitudes and perceptions about physics courses and AR learning environment.

3.2.1.Physics in-class learning experiences

Observing the details in each question item, only the index of question 5 (It's easy to summarize the results of physics experiments) (M = 3.87) is lower than average. This finding implies that most students think it difficult to summarize the results of physics experiments. In addition, we get an interesting result that although students fear to take physics courses, they are interested in some physics phenomena in our daily life, especially in handling operations of physics experiments. Based on these results, researchers reasoned that most students like to make inquiries and try new activities, including doing experiments by themselves. Therefore, teachers should try innovative instructional methods and design more realistic physics questions reflecting daily life situations in physics courses in order to emphasize students' self-oriented learning and improve their motivation.

3.2.2.AR tool instructional applications

According to the results of AR tool instructional applications questionnaire survey, most students have positive attitudes towards using AR for their learning in physics courses. The index of students' acceptance is in the medium range (M = 4.26) from 3.83 to 4.47. Questions 6 (AR instructional applications in physics courses attract my attention and stimulate my curiosity, and I want to explore more deeply into physics) has the highest mean score (M=4.47), other question items also posses mean scores higher than average, such as Question 11(The AR instructional method could promote my learning motivation for the physics course) (M=4.27), Question 12 (I extremely prefer learning physics by AR instructional tools) (M=4.40), Question 13(I am very impressed with AR instructional display and experiments) (M=4.27), Question 14(AR instructional tools can help me memorize the results of physics experiments) (M=4.30). Thus, we can know that students not only prefer learning physics by AR tools but feel quite impressed with AR instructional display and experiments, as AR instructional applications attract their attention, help them memorize the results of experiments and promote their learning motivation.

4.Conclusions

Augmented Reality, due to its virtual-real blended, real-time interactive, three-dimensional immersive characteristics, differentiates from traditional learning based on learning management platforms and three-dimensional virtual learning environments such as Second Life and Sloodle. Its three-dimensional immersive environment blending reality and virtuality provides further possibilities for teaching objects modeling, teaching process experiencing, teaching outputs presenting and teacher-student interaction. Teaching and learning activities under this environment, e.g., how to design teaching activities, how to interact through learning processes, how to evaluate learning results, etc, are all active issues worth following.

The purpose of this case study was to investigate learning attitudes of experimental group students by using AR tool instructional applications and compare the difference of eighth graders' learning achievements on convex lens image-forming experiment in two learning environments. The study revealed that mean scores indicated by the experimental group increased more than those indicated by the control group, but there appeared no significant difference between the two groups in post-tests. In addition, most students have positive attitudes towards using AR for their learning in physics courses, they think AR tool instructional applications can attract their attention and promote their learning motivation in physics courses based on the results of learning attitudes questionnaire. Although there is insufficient evidence to determine whether students' conceptual understandings can be promoted, AR tools applications provided students with different opportunities for science learning. On the other hand, AR tool experiments supported students' understandings of concrete and observable physics concepts and assisted the development of experimental skills through practical experiences.

Acknowledgements

This research was supported by grants from Beijing Natural Science Foundation (Grant No: 4123099) and State Key Laboratory of Virtual Reality Technology and Systems, Beihang University (Grant No: BUAA-VR-12KF-12).

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