Yang, J. C. et al. (Eds.) (2018). Proceedings of the 26th International Conference on Computers in Education. Philippines: Asia-Pacific Society for Computers in Education

A Comparative Study on Achievement Degree of Teaching Objectives based on an Interactive AR Physical-Simulation Experimental Procedure

Xiaojie NIU[a,c], Xueying XU[a,c], Lu CHENG[a,c] & Su CAI[a,b*]
[a]*VR/AR + Education Lab, School of Educational Technology, Faculty of Education, Beijing Normal University, China*
[b]*Beijing Advanced Innovation Center for Future Education, Beijing Normal University, China*
[c]*Joint Laboratory for Mobile Learning, Ministry of Education-China Mobile Communications Corporation, Beijing Normal University, China*
*caisu@bnu.edu.cn

Abstract: The progress of mobile devices and augmented reality (AR) plays a great role in integrating information technology and classroom teaching. By integrating field research into exploration-based experimental teaching activities, this study developed an interactive AR physical-simulation experimental procedure and created an evaluation model of Knowledge- Attitude-Process teaching objectives. During classroom teaching, the AR physical-simulation experimental procedure can present experimental models intuitively to encourage students to really interact with the AR experimental environment and enhance learning and teaching effects of experimental courses. This study researched influences of the procedure on achievement of teaching objectives of students. In this study, 70 eighth-grade students were randomly divided into an experimental group and a control group. According to descriptive statistics analysis of results of pre-tests, post-tests and questionnaire surveys, the achievement degree of teaching objectives of students who used this procedure was better than that of those who used an ordinary physical-simulation laboratory. Therefore, the interactive AR physical-simulation experimental procedure played an active role in helping students master scientific experiments and improving their inquiry ability.

Keywords: Augmented reality, Interaction, Scientific inquiry

1. Introduction

With the gradual popularization of the internet and mobile terminals, the potential of AR in education and teaching has been greatly developed and AR has been used as a new tool in respect of stimulating learning motivation, creating a learning environment and spanning time and space.

AR-related studies indicated that the introduction of AR increases possibilities of education and teaching. However, now there are still many problems relating to educational application of AR, such as simple presentation modes, shallow interactions and difficult popularization, and phenomena, including superficial integration of technology and teaching and unreasonable design of teaching activities.

This paper selected physics, a subject with high suitability of AR, to explore influences of interactive AR software on the achievement degree of Knowledge - Process - Emotional Attitude (KAP) teaching objectives of students through empirical research and contrast experiments. This paper is based on curriculum standards of high school physics and the syllabus of physical experiments, designed an interactive AR application program and a teaching program of experimental.

2. Related Work

2.1 Overview of AR

The integration of AR with other research fields stimulates its potential to produce new characteristics and functions. In terms of its integration with education, many researchers have studied the application. Shelton and Hedley (2002) applied AR-Tookit to the development of an earth-sun relation system for explanation of abstract concepts, which showed that AR could improve teaching effectiveness by enhancing resource visualization. Other AR-related studies indicated that application of AR to education could deepen understanding of learners about their learning contents (Albrecht, Folta-Schoofs, Behrends, & Von Jan, 2013); offer opportunities of hands-on practice to learners to improve their operational ability(Akçayır, Akçayır, Pektaş, & Ocak, 2016); improve learning participation and ability of cooperation and exchange of students during cooperative learning(Lin, Duh, Li, Wang, & Tsai, 2013); adapt to learning needs of different students and enhance teaching effectiveness to maintain learning motivation of students(Di Serio, Ibáñez, & Kloos, 2013).

2.2 AR improves the achievement degree of objectives of physics courses

In addition to its characteristics above, application of AR in education has covered various contents. According to analysis on AR and education from 2011 to 2016 carried out by Yu, LI, and Liu (2017), nearly half of AR education applications were related to natural sciences. This is probably because visualization of microscopic and abstract contents and real-time interactive scenes realized through AR can provide a solution for training students with four core quality of physics, namely scientific knowledge, scientific methods, scientific spirit and attitude and scientific applications, and highlighting the status of experimental subjects during the K-12 stage.

There are successful application cases about empirical research on AR learning environment of physics courses. For the impact of AR on the T&L, Jerry and Aaron (2010) conducted a qualitative and quantitative study in form of Inquiry based Learning showing that AR intervention had a positive effect on both students' learning attitude and academic achievement on Kinematics graph analysis. AR-SaBEr, a simulation tool based on augmented reality was designed and suggested effective as the learning environments of basic principles of electricity in different support for recommending activities(Ibáñez, Di Serio, Villarán-Molina, & Kloos, 2015). The study on teaching of the AR double-slit interference experiment conducted by (Wang, Zhang, Xue, & Cai, 2018) also verified that AR played a significant role in promoting auxiliary teaching and motivating students to learn.

To sum up, AR applications have covered teaching of the whole subject of physics and show a great potential in teaching practice. However, at present, most of studies focus on impact of AR on students' interests and attraction and ignore the holistic study on effects on the achievement of teaching objectives. Therefore, this paper carried out a comparative study on achievement of teaching objectives with an interactive AR physical-simulation experimental procedure.

3. Method

3.1 Program development

The app used Unity 3D to build model and Vuforia to develop the Augmented Reality function. The Vuforia can be download from the website.

3.1.1 Content selection

The single slit diffraction is a lesson in Elective Physics 3-4 of the PEP edition. Due to expensive equipment, difficult observation and abstract principles of this experiment, we chose single slit diffraction as the presentation content of the AR program and helped students to explore rules by three pictures and virtual buttons.

3.1.2 Introduction of functions

The influences of functions of AR software on studying different variables of fringe presentation were determined, where modules included: a wavelength-fringe module, a single slit spacing-fringe module and a distance-fringe module.

3.2 Teaching design

The teaching design was finished with the ASSURE model. The ASSURE model of teaching design was put forward by Robert Heinich, an educational technologist, in "Instructional Media and The Technologies for Learning" in 1989. It is an abstract scheme for instructional systems design and implementation, which shows specifically and realistically how media fit into the daily life of the classroom. (Heinich, 1999)

The course was designed for eighth-grade students aged between 12 and 14, who can conduct presupposition thinking through hypotheses with some self-awareness and monitoring ability and break the stereotype thinking. In respect of initial capacity, these students had never touched knowledge about single slit diffraction and generally had great interest in and a positive attitude toward physical experiments.

According to Bloom's taxonomy of educational objectives and learning contents, we stated educational objectives by the ABCD method and set up expressive objectives.

Students of two groups carried out the experiment with the interactive AR physical-simulation experimental procedure and the SeeLight virtual-simulation experiment platform of an optical system (http://www.seelight.net/) respectively.

3.3 Experiment

With the implementation of Curriculum Reform in Fundamental Education aimed at building the fundamental education curriculum in the 21st century, Zhong qiquan proposed the three-dimensional goal to emphasize the achievement of knowledge and skills in the course objectives, process and method, emotional attitude and values (Zhong, 2011). The Knowledge-Process-Emotional Attitude three-dimensional scale was used to build the KAP teaching model. As shown in the Figure 1.

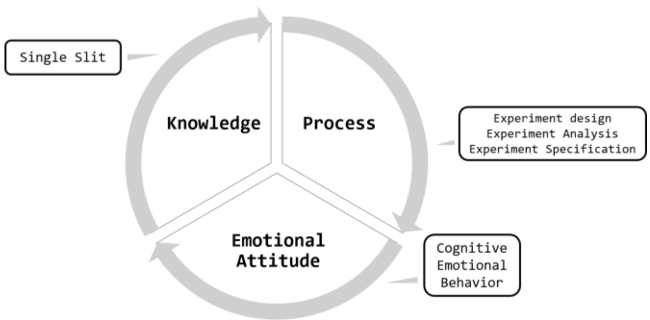

Figure 1. The KAP model

3.3.1 The process in class

This study selected the Second Junior Middle School of Wuqiao County, Cangzhou City, Hebei Province as its experimental school and set up a 35-student experimental group (Class A) and a 35-student control group (Class B). Teachers of both Class A and Class B were members of the subject group with teaching experience.

The lesson was taught in both classes at the same time for 100 minutes. Teachers created scenes, led students to think, design the experiment, operate and exchange. In Class A, the self-developed AR program was used in the exploratory link, while in Class B, the teacher played an animation film of experimental investigation in a virtual simulation environment for the link. In order to control variables, conditions were the same (such as pictures, teaching media and links used by teachers) except tools used in the exploratory link. Figure 2 shows the actual scene of teaching with the app.

Figure 2. Students in Class A used AR software in an Android system to explore

3.3.2 Data acquisition

According to the established teaching objective model, we tested students and collected data from perspectives of Knowledge, Process and Emotional Attitude.

For knowledge: In terms of knowledge of students, we chose five choice questions as basic questions and one matching question as an extended question in accordance with the teaching content.

For process: As for measurement of scientific inquiry of students, we combined pre-tests with post-tests and applied comprehensive tests to inspections of students. Students were asked to answer a physics question on the basis of their understanding. We evaluated from perspective of experimental design, experimental analysis and experimental specifications in line with answers of students.

For emotional attitude, Adams et al. (2006) proposed the Colorado State University scale about scientific attitude and verified its reliability and validity. In this study, this scale is simplified as Table 1.

Table 1

Scale about Physical Experiment Attitude(Partial)

No.	Dimension	Positive statement
1	A	I think that physical experiments are necessary.
2	B	I think I can conduct physical experiment well if I work hard.
3	C	I like to experiment independently.
…	…	…

In Table 1, A represents cognitive dimension, B represents emotional dimension, and C stands for behavioral tendency dimension.

4. Result

4.1 Knowledge

We conduct descriptive statistics on basic and extended questions. The results are shown in the Table 2. Then a T-test was performed on the total scores of the two classes of knowledge subjects, Sig = 0.025 < 0.05. There are significant differences between the two classes. The results of the extension subjects are significantly higher than those of class B. It shows that the AR interactive program can improve students' knowledge mastery, especially the more difficult extension problems.

Table 2

Descriptive Statistics of the Results of Knowledge Test

Subject	Basis		Extension	
Statistics	AVERAGE	Sd	AVERAGE	Sd
Class A	4.6	1.03	4.24	1.37
Class B	4.03	1.74	3.23	1.42

4.2 Process

We performed the statistical analysis method ANCOVA on pretest and posttest results of the scientific inquiry process subjects of two classes. The result of covariance analysis is Sig.=0.078>0.01. It means after eliminating the difference between the pre-tests, the difference between the two classes is not significant. However, after eliminating the difference between the pretests, the average score of posttest of class A is 2.149 and the average score of B is 1.560. It shows that the use of interactive AR program can benefit students' scientific inquiry process to some extent. As is shown in the Table 3.

Table 3

Data Analysis of Process Test-Estimated Marginal Means

Class	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
A	2.149[a]	.225	1.699	2.599
B	1.560[a]	.218	1.124	1.996

4.3 Emotional Attitude

Attitudes are divided into cognitive dimension, emotional dimension, and behavioral inclination. We performed descriptive statistics and a Paired Sample T tests on the results of A-class attitude scales. From Table 4, it can be seen that average value of the three dimensions has increased. There was no significant difference between the two dimensions of cognition and emotion, and there was a significant difference in the dimension of behavioral tendency.

The explanation for this phenomenon is that "cognition" refers to the understanding of the physical experiment itself, and "emotion" refers to the preference for physics experiments. Before the experiment, we analyzed the learners. The three interviewed students all said that “I think physics experiment is very important” and “I like to do physics experiment”. So we think that the students have reached a higher level in these two aspects. For both pretest and posttest, the score rates of Classes A and B have reached more than 80%. This level has been difficult to improve, so the development of this course has not caused significant impact.

Table 4

Descriptive Statistics of the Results of Process Test of Class A

	Pretest		Posttest	
Statistics	AVERAGE	Sd	AVERAGE	Sd
Cognitive	8.64	0.93	9.36	1.48
Emotional	11.42	1.51	12.33	1.54
Behavior	13.73	1.68	15.91	1.76

5. Conclusion & Discussion

During the study, the interactive AR program developed independently was used to conduct physical experiment teaching, and the data was collected by questionnaire to explore its research on the attainment of teaching objectives. The experimental results show that the interactive AR program has a positive effect on the achievement of teaching objectives.

It needs to be emphasized that in order to reasonably apply AR program in the real teaching situation, it is necessary to attach importance to the design of teaching resources, teaching activities and teaching evaluation, etc. corresponding to AR program. We need to control all aspects of the physical experiment." This is the part that needs to be paid attention to in the practice of technology integration class represented by AR technology.

In future studies, we will use AR technology cycle longer experimental research, to explore the application of AR technology for students is relatively stable characteristics (such as interpersonal skills, subject ability, etc.). In addition, how to improve the development and application of AR technology according to the feedback result of students is also one of our tasks.

Acknowledgements

This work is supported by the National Natural Science Foundation of China (Grant No 61602043) and 2018 Comprehensive Discipline Construction Fund of Faculty of Education, Beijing Normal University.

References

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical review special topics-physics education research, 2*(1), 5-16.

Akçayır, M., Akçayır, G., Pektaş, H. M., & Ocak, M. A. (2016). Augmented reality in science laboratories: The effects of augmented reality on university students' laboratory skills and attitudes toward science laboratories. *Computers in Human Behavior, 57*, 334-342.

Albrecht, U.-V., Folta-Schoofs, K., Behrends, M., & Von Jan, U. (2013). Effects of mobile augmented reality learning compared to textbook learning on medical students: randomized controlled pilot study. *Journal of medical Internet research, 15*(8), 50-77.

Di Serio, Á., Ibáñez, M. B., & Kloos, C. D. (2013). Impact of an augmented reality system on students' motivation for a visual art course. *Computers & education, 68*, 586-596.

Heinich, R. (1999). Instructional Media and Technologies for Learning.

Ibáñez, M. B., Di Serio, A., Villarán-Molina, D., & Kloos, C. D. (2015). Augmented Reality-Based Simulators as Discovery Learning Tools: An Empirical Study. *IEEE Trans. Education, 58*(3), 208-213.

Jerry, T. F. L., & Aaron, C. C. E. (2010). *The impact of augmented reality software with inquiry-based learning on students' learning of kinematics graph.* Paper presented at the Education Technology and Computer (ICETC), 2010 2nd International Conference on.

Lin, T.-J., Duh, H. B.-L., Li, N., Wang, H.-Y., & Tsai, C.-C. (2013). An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system. *Computers & education, 68*, 314-321.

Shelton, B. E., & Hedley, N. R. (2002). *Using augmented reality for teaching earth-sun relationships to undergraduate geography students.* Paper presented at the Augmented Reality Toolkit, The First IEEE International Workshop.

Wang, T., Zhang, H., Xue, X., & Cai, S. (2018). Augmented Reality-Based Interactive Simulation Application in Double-Slit Experiment *Online Engineering & Internet of Things* (pp. 701-707): Springer.

Yu, C., LI, Q., & Liu, Y. (2017). The Research Status and Trend of Educational Application of Augmented Reality:Based on Chinese and English Journal Papers Published from 2011 to 2016. *Journal of Distance Education*(04), 104-112.

Zhong, Q. (2011). On the Three-dimension Objectives. *Educational Research*(09), 62-67.