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Author(s) Zifeng Liu, Beijing Normal University; Xinyue Jiao; Yuxi Wen, Vanderbilt University; Su Cai

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Effects of Augmented Reality on Students' Online Physics Learning

Abstract: Augmented Reality (AR) has played an essential role in education, yet existing literature focuses on AR in in-person courses than online counterparts. This study developed an AR application to help students learn remotely about friction in physics. Students were divided into two groups by class to analyze the effects of AR on students' learning achievement, attitude, motivation, and cognitive load by manipulating the use of AR during the online instruction. Results indicate the use of AR for online teaching can significantly improve students' physical learning achievement, but it has no significant effect on students' learning attitude, motivation and cognitive load. The interview results confirm that AR can be further developed in online teaching in the future.

Keywords: Augmented Reality, online learning, physics learning

1. Introduction

Augmented Reality (AR) provides unique opportunities for application into the field of education (Diegmann et al., 2015). Studies have shown that adopting of AR in students' learning activities can enhance students' learning performance (Akçayır & Akçayır, 2017). Based on its ability to integrate virtual and real worlds, AR has great potential in empowering students to understand science knowledge by visualizing abstract concepts and simulating complicated experiments (Arici et al., 2019; Crandall et al., 2015). Furthermore, compared to traditional methods, the integration of AR and teaching modes allow students to better stimulate their positive emotions (Fidan & Tuncel, 2019).

However, there has been only a limited study on online AR teaching and learning of physics. Students may experience negative emotion during distance education due to telecommunication difficulties (Hara & Kling, 1999). With the increasing widespread of online education, it is necessary to study the impact of AR on students in online courses (Allen, 2011).

2. Related Works

Physics contains many abstract concepts and scientific experiments as an experiment-based discipline. AR can be used to solve difficulties that traditional physics teaching encountered, such as expensive and therefore undersupplied laboratory equipment (Cai et al., 2017). More recently, some researchers have integrated AR into other learning materials, such as worksheets, in physics teaching to practice students' high-order thinking skills (Bakri et al., 2020; Bakri et al., 2019). Others developed AR applications for visualizing abstract concepts in physics (Abdüsselam, 2014; Abdusselam & Karal, 2020; Tomara & Gouscos, 2019); applying AR to science subjects can also positively affect the attitude of the learners, increase students' motivation (Arici et al., 2019) and make them receive experiences that are difficult to access in traditional classroom settings (Morales et al., 2019).

As a form of education, online teaching with rigorous design can achieve the same outcome as in-person courses in many aspects (Jones & Hill, 2015). Numerous studies have shown that technology is one of the major factors affecting students' learning performance in online education (Eom & Nicholas, 2016; Volery, 2016). However, compared with offline learning, students are less likely to engage in collaborative learning and interaction (Dumford & Miller, 2018). The lack of interaction in online courses can cause students to stop learning (Faulconer et al., 2018; Mullen & Tallent-Runnels, 2006). To increase the interactivity in class, some scholars use the virtual world as a learning environment in online courses (Petrakou, 2010). It indicates that AR has the potential to improve the efficiency of online education.

Thinking back to the previous point, most of these studies focuses AR in offline learning and analysis of alternative teaching methods remains largely unexplored. Therefore, we analyzed the effects of AR on students in an online course to explore whether AR can benefit online teaching.

3. Methods

3.1 Participants and Procedure

Seventy-two students from a public high school located in an underdeveloped area participated in the study. *Table 1* presents details of the sample and procedures. Participants all had experience of using mobile devices for learning. A quasi-experiment was designed in this study. Students were divided into two groups by class, namely the experimental group (EG) and the control group (CG). The EG students used AR in the learning process, and the CG students used traditional methods to learn. The structure of the study were shown in *Figure 1 Structure of the StudyFigure 1*.

3.2 Research Questions

Research Questions (RQ) are as follows:

RQ1: Compared with traditional teaching methods, can AR benefits students' (1) learning achievement, (2) attitude, and (3) motivation in online courses?

RQ2: What are the effects on students' cognitive load when AR is implemented in online courses?

RQ3: What are students' conceptions about using AR for online learning?

3.3 AR Application Design

The AR application designed and developed in this study contains two main scenes as shown in *Figure 2*. The first scene presents a deer pulling a sleigh, in which users can modify the material of the ground to make the sleigh move or standstill. The second scene is an abstract representation of the first scene, in which the force of the object is visualized in real-time and users can adjust the mass of the object and the pulling force on the object to explore the type and measurement range of friction. As shown in *Figure 3*, the application is used in the online class to learn concepts and experiments.

3.4 Measuring Tools

Measuring tools of this study is shown in *Table 2*. Knowledge of friction was assessed in pre-test and post-test. The learning attitude questionnaire was adapted from Hwang (Hwang et al., 2013) , all evaluated from a five-point Likert scale. The learning motivation questionnaire was developed by Wang and Chen (Sup & Sup, 2010), consisting of three items of intrinsic motivation and two items of extrinsic motivation, all evaluated from a five-point Likert scale. The cognitive load questionnaire also used a scale designed by Hwang (Hwang et al., 2013), consisting of two dimensions of mental load and mental effort, all evaluated on a seven-point Likert scale. The interview questions were adapted from Hwang (Hwang et al., 2009), included in *Table 3*.

4. Results

4.1 Learning Achievement

We used paired-sample t-test to analyze the differences in physics knowledge test scores between the two groups, its results shown in *Table 4*. The post-test scores of the EG were significantly higher than the pre-test scores ($p < .001$), while the CG did not ($p > 0.5$). It implies that students who used AR during the process significantly increased their learning performance in friction; this generalizes to the inverse of the statement.

Moreover, we used the pre-test score as a covariate and the post-test score as an independent variable for covariance analysis. After conducting a homogeneity test, and the results indicate that covariance analysis can be performed (F (1,70) = 0.146, $p > .05$). The results of covariance analysis are shown in the following *Table 5*, excluding the effect of pre-test scores, the post-test scores of the two groups are significantly different (F (1,70) = 6.17, $p = .015$). The scores of EG is significantly higher than the CG, which means that using AR for online teaching is better than traditional methods in improving students' learning achievement.

4.2 Learning Attitude

To compare the differences about the learning attitude of the students in the two groups, one-way ANOVA was analyzed. The results are shown in *Table 6*. The average attitude score of the EG was higher than that of CG (EG = 4.36, CG = 4.32). The learning attitude of both groups was both high, but there was no significant difference between groups (F (1,70) = 0.065, p = .80). It would imply that in this online course, the use of AR has no notable effect on students' learning attitudes.

4.3 Learning Motivation

Similarly, we used one-way ANOVA to compare the differences in the learning motivation of students in two groups. The results are shown in *Table 7*. In general, there is no significant difference in learning motivation between EG and CG (F (1,70) = 2.973, p = .089). Specifically, the average learning motivation of EG is slightly higher than CG, but again, insignificant. Results indicate that students' learning motivation in online courses is not affected by AR in our study.

4.4 Cognitive Load

The study also explored the impact of AR on students' cognitive load in an online course. We examined the differences in cognitive load scores among students. The results of the analysis of a ANOVA are shown in *Table 8*. There is no significant difference in cognitive load between the two groups (F (1,70) = 1.515, p =.223), which implies that using AR in online courses does not increase students' cognitive load.

4.5 Interview Results

Five students were randomly selected from the EG to conduct the online interviews. When referring to the differences between using AR and traditional learning methods, four students said that the use of AR can help them understand the knowledge, and can increase the interest of learning. Compared to traditional teaching methods, online course with AR is more vivid and intuitive. Some students mentioned that one shortcoming of AR is that more pre-class preparations are required, such as installing software. Regarding students' attitudes towards using AR online, all students think AR is good for teaching, and they can adapt to this kind of online learning with AR. Besides, the students interviewed agreed that they want other teachers to use AR for teaching in class. In general, the use of AR technology in an online course can help students learn abstract knowledge, allowing them to obtain a more vivid and rich learning experience.

5. Conclusion and Discussion

Through the use of related AR software in an online course, this study analyzes the effects of AR on students' learning performance, attitude, motivation, and cognitive load in online education. The results show that AR-based online learning activities can help students understand the abstract concept of friction and improve students' performance. It is similar to previous results of offline related research (Sahin & Yilmaz, 2020; Wu et al., 2017). AR has the characteristics of simulation and interaction, which can vividly and stereoscopically visualize abstract knowledge, and help students to carry out actively exploration and learning. In online courses, there is a lack of teacher-student interaction due to distance, so students are more likely to passively accept knowledge. Fortunately, the use of AR can reduce this circumstance and provide conditions for students to learn actively.

According to the quantitative data analysis results of this study, the use of AR in an online course has no significant effect on students' learning attitude, learning motivation, and cognitive load. First of all, for students who participated in this study, they are still in an adaptation stage because online learning is originally a quite new learning scheme for them. The impact of AR on these three factors may not as obvious as the change of offline learning to online learning. Besides, online education is largely affected by the role of teachers (Gómez-Rey et al., 2018). In this online course, the consistency of the teacher's instruction and expression in the two groups may affect the students' learning attitude and motivation. Moreover, the level of intrinsic motivation of distance education students in e-learning environments is very high (Firat et al., 2018), which may cause the use of AR not to affect students' motivation significantly. A large amount of information on the Internet distracts students (Weigel et al., 2010), for example, in this online course, some students quitted or entered the course in the middle.

From the interview results, we can know that the use of AR in online courses can be accepted by students, but the specific impact on their learning attitude and motivation is not significant. Previous studies have shown that online courses may cause students' performance to deteriorate, and it is more obvious for specific groups of people (Xu, 2013).Therefore, there is room for improvement in the way of using AR online in this study. It's worth combining some suitable instructional design to explore the impact of AR in online courses in the future.

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Table 1 Symbolic representation of the sample and procedures.

Group	***Number***	***Male/Female***	***Avg. Age***	***Procedures***			
				Stage 1	***Stage 2***	***Stage 3***	***Stage 4***
CG	28	19/9	16	Pre-test	Online Learning	Post-test	Interview
EG	44	38/6	16				

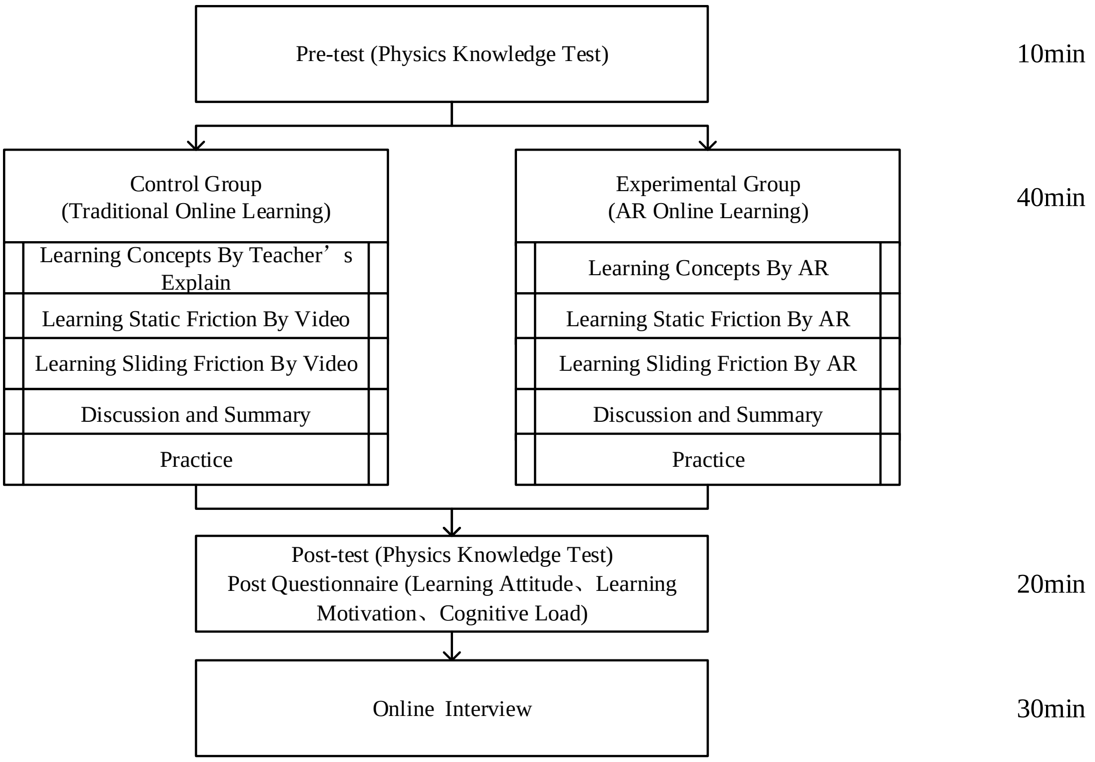

Figure 1 Structure of the Study

Figure 2 Screenshots of the Scenes

Figure 3 Screenshots of the Online Class

Table 2 Measuring Tools of the study

Measuring Tools		***Items***	***Points***	***Cronbach's α***
Physics Knowledge Test	Pre-test	10	100	0.8
	Post-test	10	100	0.7
Learning Attitude Questionnaire		7	35	0.92
Learning Motivation Questionnaire		5	25	0.81
Cognitive Load Questionnaire		8	56	0.97

Table 3 The Interview Questions

Interview Questions
How is the teaching in this way different from the way you have experienced before?
What do you think are the advantages of this learning method?
Which part do you think you get the most with this method? Which part did you learn the most?
What needs to be improved in this way of learning?
Do you hope to have the opportunity to learn this way again in the future?
Would you recommend others to use this system or this way to study?
Would you recommend teachers to use this system or such a way to teach?
Is there any difference between the acceptance of AR before the class and after the class?
Did you encounter any difficulties during class?
Did you communicate with others about our AR software or friction learning after class?

Table 4 The Paired t-Test Results for Pre-Test and Post-Test Score Variables of Two Groups

Group	***N***	***Pre-test (SD)***	***Post-test***	***MD***	***t***	***df***
CG (traditional online learning)	28	67.14(24.07)	72.56(11.67)	5.42	-1.38	27
EG (AR online learning)	44	56.36(22.06)	77.87(14.65)	21.51	-6.45^{***}	43

$^{***}\ p < .001$

Table 5 The ANCOVA Results of the Students' Physics Knowledge Test

Group	***N***	***M(SD)***	***Ad M***	***SE***	***F***	**η^2**
CG (traditional online learning)	28	72.56(11.67)	71.05	2.42	6.17^{*}	.082
EG (AR online learning)	44	77.87(14.65)	78.83	1.92		

$^{*}\ p < .05$

Table 6 The ANOVA Results of the Students' Learning Attitude

Group	***N***	***M(SD)***	***SE***	***F***
CG (traditional online learning)	28	4.33(0.64)	0.12	0.065
EG (AR online learning)	44	4.36(0.58)	0.09	

Table 7 The ANOVA Results of the Students' Learning Motivation

Group	***N***	***M(SD)***	***SE***	***F***
CG (traditional online learning)	28	4.04(0.63)	0.12	2.973^{*}
EG (AR online learning)	44	4.30(0.63)	0.09	

$^{*}\ p < .05$

Table 8 The ANOVA Results of the Students' Cognitive Load

Group	***N***	***M(SD)***	***SE***	***F***
CG (traditional online learning)	28	3.57(1.60)	0.31	1.515
EG (AR online learning)	44	4.03(1.41)	0.21	

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