The Effects of Visualization Strategies on Students' Learning Outcomes in Augmented Reality Contexts

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Abstract: This study attempted to investigate the effects of visualization strategies on electrical-machinery course of vocational high school students' learning outcomes in augmented reality (AR) contexts. Hence, A learning environment combined with visualization strategies and AR technology were developed in this study. To exploring the effects of visualization strategies, a quasi-experimental design was conducted in this study. The participants of this study included 63 seventh-grade senior high school students from two classes in Taiwan. Two classes were randomly assigned into control and experimental groups. Students in control group learned with AR technology while those in experimental group learned with visualization strategies and AR technology. The results revealed that students in experimental group outperformed than those in control group.

Keywords: Augmented reality, visualizations, electrical-machinery, vocational high school

1. Introduction

The emergence of the AR technology has been continuously rebuilding students' learning experience. One of the major advantages of the AR technology includes its potential to authentically augment people's experience in the real world (Wu, Hwang, Yang, & Chen, 2018), which may help learners obtain abstract concepts or perceive unobservable phenomena in a multidimensional way (Xu, Su, Hu, & Chen, 2022). Research results have commonly suggested that individuals may benefit from the AR-enhanced learning environment with increased motivation and engagement (Cai, Chiang, & Wang, 2013), positive attitudes (Behzadan & Kamat, 2013), learning gains in language learning (Cai, Pan, & Liu, 2022), and high levels of reading comprehension (Bursali & Yilmaz, 2019). However, while it is believed that students may profit from the AR technology in improving academic achievement (Lu, Liu, Chen, & Hsieh, 2020; Sahin & Yilmaz, 2020), some studies do not reveal such positive effects (Lai & Chang, 2021). Moreover, in a review conducted by Chang, Binali, Liang, Chiou, Cheng, Lee and Tsai (2022), learners seem to show more positive responses (e.g. learning motivation or attitude) in learning arts-related subjects than those in science.

Indeed, most research has shown promising efficacy on the AR technology in promoting students' learning outcomes (e.g. Chang & Hwang, 2018; Sahin & Yilmaz, 2020), and some research has suggested that the AR technology utilized with the collaborative pedagogical approach may display higher impact on students' learning outcomes (Garzón Kinshuk, Baldiris, Gutiérrez, & Pavón, 2020). However, it is noted that relative few studies have been found in suggestion of pedagogical strategies in implementing the AR-enhanced educational context. As the importance of visualization strategies have been emphasis in science edcuation (Ainsworth, Prain, &Tytler, 2011; Chang, Quintana, & Krajcik, 2010). Hence, it is worthwhile to investigate the effects of visualization strategies in the AR-

enhanced educational context so that better AR-enhanced learning environment may be established.

2. Methods

2.1 Participants

The participants of this study included 63 seventh-grade vocational high school students from two classes in Taiwan. Two classes were randomly assigned into control and experimental groups. Students in control group (n = 35) learned with AR technology while those in experimental group (n = 28) learned with visualizations and AR technology.

2.2 Research Process

All the students in two groups enrolled in electrical-machinery courses with the same instructor. At first, all the students were asked to fill in pretest to assess their prior knowledge. During the learning activity, the students in experimental group were learned with visualizations and AR technology while those in control group were learned with AR technology. After the learning activity, all the students in two groups were asked to complete a posttest to understand their learning performance.
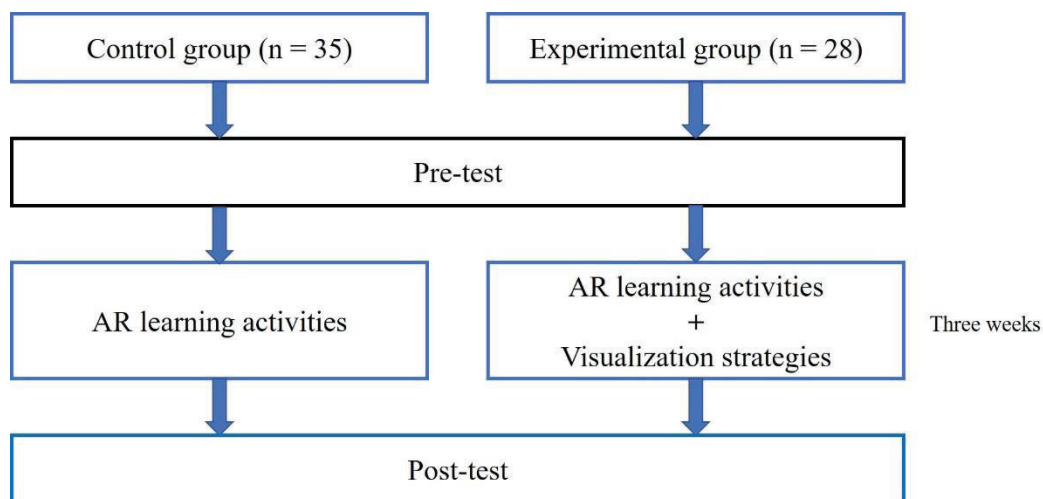

Figure 1. Research process in this study.

2.3 Instruments

2.3.1 AR technology

A learning environment combined with visualization strategies and AR technology were developed in this study. The learning materials in text book and AR context were shown in Figure 1 and Figure 2.
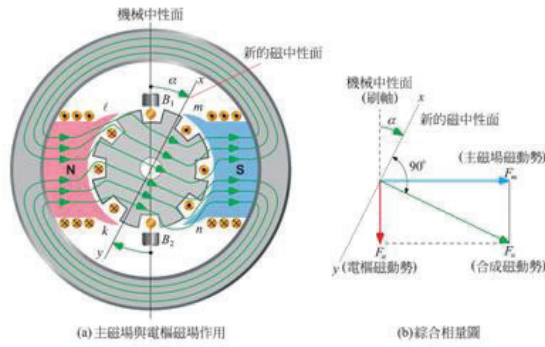
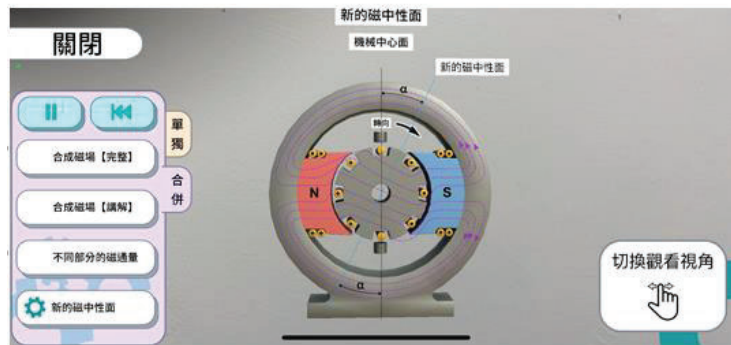*Figure 2*. The learning materials in textbook.

Figure 3. The learning materials in AR context.

Figure 3 shows a student learns with AR technology. The student can not only browse the learning materials in mobile devices, but also interact with the learning materials to acquire more abstract knowledge or to conduct inquiry learning activities.

Figure 4. An example of a student learns in AR context.

2.3.2 Learning Outcomes

The learning outcomes in pre-test and post-test were developed by two vocational high school teachers. Each test consisted of 15 questions by using two-tier tests. The questions were validated by a teacher and a professor for expert validity.

2.3.3 Data Collection and Analysis

To explore the effects of the visualizations on the students' learning outcomes in AR contexts, this study used the students' pre-test data as the covariate and post-test data as a dependent variable to run the one-way ANCOVA analysis

3. Results

A one-way ANCOVA was used to compare the effect of the two teaching strategies while controlling for the pre-test scores. As shown in Table 1, the results revealed that students in experimental group outperformed than those in control group ($F(1,59) = 4.24$, $p < 0.05$). It showed the effects of visualization strategies in AR learning outcomes.

Table 1. *ANCOVA results*

Source	SS	DF	MS	F
Intercept	275911.20	1	275911.20	233.16*
Pre-test	122.51	1	122.51	0.45
Teaching strategies	1152.29	1	1152.29	4.24*

4. Conclusion

This study investigated the effects of visualization strategies on vocational high school students' learning outcomes in augmented reality (AR) contexts. The results revealed that students in experimental group outperformed than those in control group. It implied the importance of using suitable teaching strategies into innovative technology into instructions. It is suggested that future studies can investigate the effect of combinations of different teaching strategies and AR technology in AR learning contexts.

Acknowledgements

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