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Investigating the Learning Performance toward Geometry Learning in an Augmented Reality System

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Abstract: The purpose of this study was to investigate the effect of Augmented Reality (AR) assisted learning environment on students' learning performance. A total of 30 students were invited to learn the topic of geometry in different instructional settings. One group of students learned geometry with only paper information, another with paper information and real bricks, and the other with an Augmented Reality system (AR App). To examine the learning performance, students were tested with the Mathematics Achievement Test (MAT) before and after the geometry learning. The result showed that there was significant difference in the learning achievement (post-test) among the three study groups. Students of AR group obtained the highest scores in MAT.

Keywords: geometry learning, learning performance, augmented reality

1. Introduction

Geometry has been viewed as an important learning topic in the international assessments, such as Programme for Informational Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS). Educational researchers have conducted many studies to examine how to help students learn better with different resources. Several studies showed that using information technology (IT) can enhance learners' interest toward geometry learning and also promote learners' understanding of abstract concepts (e.g., Chang, Sung, & Lin, 2007). Students, especially with the low academic performance, considered the geometry concept abstract and difficult to understand. With the integration of mathematical software program (e.g. Geogebra), students' learning on geometry was improved (Bhagat, & Chang, 2015). It has been argued that spatial ability affects science and mathematics learning (eg., Chen & Yang, 2014). Saha, Ayub, and Tarmizi (2010) showed that students with low spatial ability learned geometry better with Geogebra program compared to those who were taught with traditional method. In short, with the assistance of information technology, teachers and educators could help students learn geometry better. In this study, we focused on one type of information technology - Augmented Reality (AR), and the purpose of the study was to examine how the AR system affected students' learning achievement on the topic of geometry.

In literature, researchers in different research fields (such as computer sciences and educational technology) gave different definitions for AR. (Wu, Lee, Chang, & Liang, 2013). For example, Azuma (1997) specified AR as a system with three features: a link between real and virtual worlds, real-time and instant interaction, and 3D objects for virtual and real world. Klofer (2008) pointed out a spectrum showing how mush AR included in the task, from the highly to lightly AR. According to Klopfer, the level of AR was defined depending on how much virtual information and real objects were provided to learners. All these studies argue that AR actually played a

supplemented role rather than a replacement of reality. The AR applications have been growing in recent years but how far the AR applications can help student learn school subjects is an issue to be widely explored.

Based on the above discussions, we attempted to examine the geometry learning achievement in the AR assisted learning environment. We expected to find that the use of AR could indeed help students learn better the topic of geometry (related to 3D concept).

2. Methodology

2.1 Research design and sample

The present study employed pretest-post-test only true experimental design. A total of 30 Chinese middle school students, aged 12-13 years, were divided into three groups of 10 students, including: one control group (CG) and two experimental groups (EG1 and EG2).

2.2 Instruments

Mathematics Achievement Test (MAT) was employed to measure students' learning achievement. Pre-test and post-test both had the same test items, but the order was changed. The test items were comprised of 18 multiple-choice questions based on the concept of 3-dimensional (3-D) geometrical shapes and validated by a group of subject experts. The overall Cronbach's α of the instrument was above 0.7, which is acceptable (Barrett, 2001).

2.3 Procedure

All students were asked to finish the MAT test first as the pretest. Then, students in different groups were provided with different learning materials. Students in control group (CG) only acquired the paper information about different geometry shapes. Students in experimental group 1 (EG1) were given the real bricks of different shapes and paper information as well. Students in experimental group 2 (EG2) were asked to learn the geometry shapes and related information with an AR system shown on iPad. After students finish learning of the geometry shapes, they were given the MAT test again as the posttest.

2.4 Data analysis

One-way analysis of co-variance (ANCOVA) was conducted to analyze learning achievement scores and learning motivation respectively. All analyses were conducted using the statistical package for the social sciences version 21 (SPSS 21). The statistical significance level was set at $p<0.05$.

3. Results

3.1 Learning achievement

Table 1 summarizes the descriptive statistics for achievement scores for each group. Levene's homogeneity test was conducted and no violation was found (F=2.37, p>.05). Therefore, ANCOVA was conducted. The ANCOVA results showed that there was significant difference in the learning achievement among the three groups, F (2, 26) = 3.39, p < .05, η^2 = .2, which is considered to be a small effect (Cohen, 1988).

Table1.

Descriptive Statistics for Achievement Scores

	Group	Mean	*SD*
Pre-test	CG	11.90	1.37

	EG1	12.90	1.91
	EG2	12.80	2.61
Post-test	CG	13.60	1.50
	EG1	12.70	2.16
	EG2	14.70	1.33

Table2.
ANCOVA Results for MAT Post-Test Scores

Source	*SS*	*df*	*MS*	*F*	*p*	η^2
Pre-test	1.22	1	1.22	.413	.52	.01
Group	20.2	2	10.1	3.39	.04	.20
Error	70.37	26	2.97			
Total	5702	30				

$^{*}p<.05$

4. Discussion and Conclusion

It was found that there was a significant difference in learning achievement among three groups. Experimental group 2 (EG2, the AR group) with the aid of AR learning system obtained the highest posttest score. This result was consistent with previous studies, which showed that information technology could help students learn better. Surprisingly, the control group who received the lowest scores in the pretest obtained achievement scores higher than that of the EG1 who learned the geometry with real bricks along with the paper information. This result suggested that without further instructional guidance, 3D objects might be limited in assisting learning.

The result of the study suggests that the AR assisted learning environments can promote learning achievement. However, which parts of this learning environment that exactly help students learn better have not been studied yet. If researchers and educators can map students' learning process in the AR assisted learning environment, they will know better how to design an effective AR system to promote students' learning. For the future study, it is suggested that the associations between learning process, learning achievement and learning motivation in the AR assisted learning environments should be studied. Interview and the eye tracking technique could be good methods to detect the dynamic process of geometry learning.

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