Understanding How Learner Outcomes Could be Affected through the Implementation of Augmented Reality in an Introductory Engineering Graphics Course

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Abstract

The study was designed to investigate the implementation of AR in an introductory engineering graphics course. In order to investigate the potential of AR, the software and assignments were aligned with course content. The study was driven by three research questions that examined how AR influenced student motivation, enhanced the learning experience, and/or affected the spatial visualization ability of students. To address these questions the three data collection methods used were the MSLQ, PSVT-R and student questions. The MSLQ results indicated that AR had a positive impact on the student's intrinsic motivation. The PSVT-R results showed an increase of spatial visualization scores. The student questions revealed that the students enjoyed the experience and believed that it was beneficial to their success in the course. Overall, the results from the two instruments and student questions were inconclusive, but the compilation of data highlights the potential of the technology and builds upon previous research.

Introduction

The study was designed and built upon previous research surrounding the use of *augmented reality* (AR) in engineering graphics courses (Chen, Chi, Hung, & Kang, 2011; Haley-Hermiz, et al., 2012; Huffman & Miller, 2012). The intention was to investigate the effectiveness of AR as a supplemental learning tool in an introductory engineering graphics course. The study investigated the impact of AR from three different perspectives. For one, the study was designed to determine how AR affected the motivational attitudes of students. Additionally, the study examined the role of AR as a tool to improve spatial visualization skills of students. Finally, the study investigated how students were able to manipulate, experiment, and engage with the augmented models.

Methodology

The sample used in the study consisted of 50 ($N = 50$) students from two different sections of an introductory engineering graphics course at a large public southeastern university. The majority of the sample population was male (70%) and predominately composed of engineering majors (92%). For most of the students this was their first engineering based course.

The AR intervention was conducted over six weekly sessions. Each session lasted for 90 minutes and required students to complete an assignment with the assistance of AR. All of the assignments aligned with the course content and were designed to reinforce previously taught engineering concepts. Upon entering the classroom students were given an iPad with a pre-loaded AR model that aligned with an assignment from the course book. Students then used the AR model to assist them in the creation of the assignment in SolidWorks.

Results

To measure the effectiveness of the AR system used in the study, multiple data collection methods were incorporated. This consisted of two different measurements: *Motivated Strategies Learning Questionnaire* (MSLQ), *Purdue Spatial Visualization for Rotations* (PSVT-R), and seven questions involving the approach of basic interpretive methodology on the student experience with AR. Both the MSLQ and PSVT-R used a pre- and post-test format, while the seven-questions were administered at the conclusion of the study. The use of a pre-test-intervention-post-test design is an appropriate method of investigation to determine the effects of innovations on education (Dugard & Todman, 1995).

MSLQ. The MSLQ was selected because of its ability to measure student motivation (Pintrich, Smith, Garcia, & Mckeachie, 1993). An abbreviated version of the MSLQ was used in the study and has been used in numerous studies (Bye, Pushkar, & Conway, 2007; Clark, Ernst, & Scales, 2009; Matthews, 2004). The abbreviated MSLQ consisted of five motivation subscales and an overall MSLQ score. The first subscale, intrinsic goal orientation, was the only subscale to show a statistical difference between the pre- and post-test scores (p = .01) see table 1. Subscales of extrinsic goal orientation, task value component, control of learning beliefs, and self-efficacy showed no statistical difference between pre- and post-test scores. In addition, there was no statistical difference between the pre- and post-tests scores on the overall MSLQ survey. Based on these findings, the null hypothesis that AR will have no significant impact on the motivational attitudes of students was not rejected.

Table 1

Paired Samples Test for MSLQ Subscales and Overall Summary

				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	Df	Sig. 2-tailed
Intrinsic Goal Orientation	-.22	1.26	.09	-.4	-.05	-2.48	198	.01
Extrinsic Goal Orientation	.04	1.32	.09	-.15	.22	.38	199	.71
Task Value	.01	1.23	.07	-.13	.15	.14	298	.89
Control of Learning Beliefs	.05	1.22	.09	-.16	.22	.52	197	.60

Self-efficacy – Learning Performance	-.06	1.22	.06	-.18	.06	-.99	398	.32
Overall Pre-Post	-.04	1.25	.03	-.11	.03	-1.1	1299	.27

PSVT-R. The PSVT-R is a spatial ability test that provides students with an object and then rotates this object and asks the student to select the correct rotation (Guay, 1980). The PSVT-R was selected because it has been commonly used in engineering and technology fields to measure spatial ability (Blasko, Holliday-Darr, & Trich Kremer, 2009; Fleisig, Robertson, & Spence, 2011; Yue, 2006). The results of the paired t-test showed a significant statistical (p = .01) difference between the pre- and post-test PSVT-R scores. Based on these findings the null hypothesis that AR will not improve the spatial visualization skills as measured by the PSVT-R was rejected (table 2). The conclusion that can be drawn from this finding was that there was a relationship between the use of AR and improved spatial visualization skills. Since there was no control group used in the study the researcher could not associate gains on the post-test PSVT-R solely to the use of AR. It should be noted that there could be other contributing factors for the increase in post-test PSVT-R test scores.

Table 2

Paired Samples Test for PSVT-R

				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	T	Df	Sig. (2-tailed)
Pre – Post PSVT-R	1.280	.8826	.125	1.53	1.036	-10.267	49	.001

Student Questions. Seven questions were developed to investigate the students' experiences with AR. The questions were initially derived by a study conducted by Chen et al. (2011) and were reinforced by additional studies that incorporated the use of post-test surveys and questionnaires (Borrero & Márquez, 2011; Fernandes & Sánchez, 2008). Several themes transcended more than one question and were merged together to create a final list of themes that can be concluded from the students' responses. First, students believed working with the AR software was enjoyable and fun. Second, students thought that AR improved their visualization ability. Third, the inclusion of AR aided students in their ability to understand and conceptualize assignments. Fourth, AR allowed them to examine the assigned models through manipulation. Fifth, the students believed AR provided an additional perspective which showed hidden features, allowed them to view the model from many angles, and check and compare the assigned models. Sixth, students associated the used of AR increased interest in the content. Seventh, students noted that AR served as a motivational tool. Finally, the student responses stated that additional refinement of the AR system was necessary in order to increase the effectiveness of the application.

Conclusions

Individually, the results from each of the data collection methods were inconclusive, but collectively the results highlight the potential of AR within education. From the combination of these results a few themes emerged. For one, the results from the collection of assessments indicated that AR has the potential to influence the motivational attitudes of students. The results of the MSLQ paired t-test indicated that a student's intrinsic motivation was positively impacted through the use of AR. The student questions added to these findings by allowing the participants to describe how AR impacted their motivation in the course. Next, the combined results of the PSVT-R and student questions hinted at a potential relationship between the students' spatial visualization development and AR. The results of the PSVT-R paired t-test showed an increase in visualization skills between the pre- and post-test scores. However it was noted that the results could not be solely attributed to the inclusion of AR and other factors could have influenced the results. The responses to the student questions added to these findings with the vast majority of students believing that their spatial visualization ability was improved through the use of AR. Lastly, the collection of assessments indicated that AR positively impact the learning experiences. The student questions provided several examples of how AR aided in the learning process, which was supported by the increase in intrinsic motivation evident in the MSLQ and increased spatial visual scores found in the PSVT-R. Additional research is required to further investigate the findings of this study, but the results obtained in this study highlight the benefits of AR in education and add to the growing wealth of knowledge.

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