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Augmented Reality Computer-aided Design Education (ARCADE) Tool to Improve Student Motivation, Engagement, and Spatial Cognition

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He was also nominated for 2004 UNI Book and Supply Outstanding Teaching Award, March 2004, and nominated for 2006, and 2007 Russ Nielson Service Awards, UNI. Dr. Pecen is an Engineering Technology Editor of American Journal of Undergraduate Research (AJUR). He has been serving as a reviewer on the IEEE Transactions on Electronics Packaging Manufacturing since 2001. Dr. Pecen has served on ASEE Engineering Technology Division (ETD) in Annual ASEE Conferences as a reviewer, session moderator, and co-moderator since 2002. He served as a Chair-Elect on ASEE ECC Division in 2011. He also served as a program chair on ASEE ECCD in 2010. He is also serving on advisory boards of International Sustainable World Project Olympiad (isweep.org) and International Hydrogen Energy Congress. Dr. Pecen received a certificate of appreciation from IEEE Power Electronics Society in recognition of valuable contributions to the Solar Splash as 2011 and 2012 Event Coordinator. Dr. Pecen was formerly a board member of Iowa Alliance for Wind Innovation and Novel Development (www.iawind.org/board.php) and also represented UNI at Iowa Wind Energy Association (IWEA). Dr. Pecen taught Building Operator Certificate (BOC) classes for the Midwest Energy Efficiency Alliance (MEEA) since 2007 at Iowa, Kansas, Michigan, Illinois, Minnesota, and Missouri as well as the SPEER in Texas and Oklahoma to promote energy efficiency in industrial and commercial environments.

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Augmented Reality Computer Aided Design Education (ARCADE) tool to improve student motivation, engagement, and spatial cognition.

Abstract

Immersive technologies such as Virtual Reality (VR) and Augmented Reality (AR) have become the worldwide huge technological innovations impacting on human life significantly. While the VR is an enclosed environment separated completely from the real world, AR allows users to merge the digital and physical worlds and enable the interaction between them. The wide usage of AR has led researchers to investigate its potential capability in several areas including STEM-related fields. Previous research shows that an AR assisted courses tend to enhance students' learning, spatial cognition, increase the students' motivation and engagement in learning process. In this study, the researchers have developed an AR application, named ARCADE to assist students with spatial cognition and remote course engagement independently. The ARCADE tool enables students to not only visualize the isometric product from its orthogonal views, but it also provides short tutorial clips how a specific feature was developed and what tools were` used. The students can perform basic modifications on the 3D part in the ARCADE such as section views, details views, scale, rotate and explode the assembly views. Although this project is a work in progress, the preliminary pretest and posttest results show there is a significant improvement in students' spatial cognition when the proposed tool is used to assist the course.

Introduction

The development of technology has led to the high demand in engineering design careers that undergo required training involved with innovative technology. Computer-Aided Design (CAD) have become an essential tool for engineers and other STEM-related fields, which requires an adequate spatial cognition skill (Sorby et al. 2013). Strong spatial skills are necessary to not only complete the engineering course but also to succeed in professional practice after finishing the curriculum (Hsi et al., 1997). Improving students' interpretation, analysis, and visualization of models, as well as their orientations, is one of the main learning objective of CAD courses. Conventional CAD courses teach 3D modeling techniques from their two-dimensional blueprints and develop complex assembly systems. Notwithstanding the covered concepts, the students may still find it difficult to visualize 3D objects, merely through their 2D orthogonal projections, as this requires a sufficient spatial cognition skill (Hsi et al., 1997). The purpose of this study is to develop an Augmented Reality (AR) enhanced training module to enable students to recognize three dimensional features of 3D models from their 2D drawings. Additionally, the researchers investigated the effectiveness of AR enhanced training modules on student motivation and engagement.

AR was first invented during the mid-twentieth century and rapidly advanced to modify the reality perception (Sutherland, 1968) as the AR overlays virtual computer-generated objects onto the real world (Dakeev, 2018). This paper discusses the outcomes of experimental novel interactive training module in college CAD courses for students from freshmen to senior years.

Background

Over the last decade, AR has served in entertainment (Ha, 2007; Rauschnabel, 2017) and marketing industries (Chylinski et al., 2020; Javornik, 2016) to improve customer experience. In consumer marketing field, AR can influence customer satisfaction and brand usage when retailers have adopted AR feature in their digital marketing platform (McLean & Wilson, 2019). Additionally, researchers (Barazov et al., 2017; Dakeev & Yildiz, 2018; de Souza Cardoso, 2019; Ibáñez et al., 2019; Sahin & Yilmaz, 2019; Scaravettia & Doroszewski, 2019) have developed innovative pedagogical tools to enhance student retention in higher education. Izbanez and his colleagues (2019) conducted a study on the effectiveness of augmented reality technology as a learning tools in geometry courses. The study suggests AR-based learning activities fostered high level of attention, relevance, and satisfaction (Izbanez et al., 2019). Sahin and Yilmaz (2019) developed a booklet integrated with AR technology for science education in middle school. The method gained the higher levels of science achievements and positive attitude towards the courses. Students who were able to experience the AR applications associated with the solar system concept, one of the topics in the science courses, can grasp the concepts easier and consequently, achieve greater academic outcome (Sahin & Yilmaz, 2019). Early education for kindergarten and elementary students (Dakeev & Yildiz, 2018) revealed that the engagement level of children significantly increases with an AR assisted teaching.

Integration of AR allows users to replay the given information without the repetition of instructors' demonstration, which might result in timesaving and economically effective potential (Bazarov et al., 2017). Bazarov and his colleagues (2017) developed an AR-based learning module for a practical engineering course, that shows a high degree of students' interest in training, which can lead to the overall high satisfaction and motivation in learning process (Bazarov et al., 2017). Particularly, in STEM-related fields, researchers have conducted several studies to examine the ability of AR in improving students' engagement and information retention in STEM education (Akçayır et al. 2016, Coimbra et al., 2015, Martín-Gutiérrez et al., 2015, Luis et al., 2013, Yen et al., 2013). Outcomes of those studies have proven that emerging AR technology can effectively improve users' visualization by superimpose the computerized concepts into the real physical world through digital devices resulting in better concepts comprehension.

In engineering training program, AR module has also been developed for a mechanical engineering training course (Scaravettia & Doroszewski, 2019). The study of Scaravettia & Doroszewski (2019) noticed that the relevant information about the complexity of a mechanism is extracted easier with the support of AR modules. This result also suggests the potential ability to shorten and enhance learning process in the specific mechanical engineering training (Scaravettia & Doroszewski, 2019).

Methodology

Researchers developed an AR application (ARCADE) in Creo Parametric, Unity Engine, and Vuforia platform. Image targets are technical drawings with projected views of a 3D objects created by Creo Parametric (Figure 1). The application installs on mobile devices and track target images to show the virtual 3D objects on the two-dimensional drawings (Figure 2).

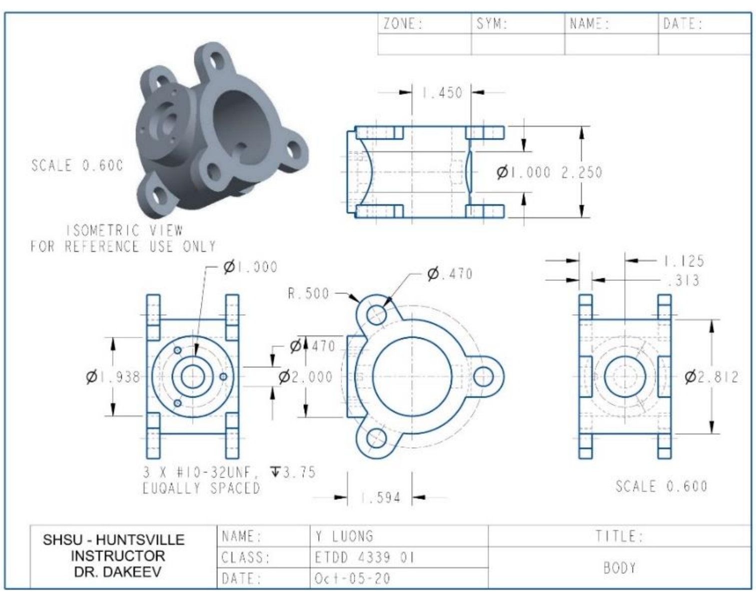

Figure 1. 2D blueprint of a part model.

Additionally, the AR application allow users to interact (rotate, scale) with the 3D objects (Figure 2a) overlaid on the drawing surface. When in doubt, the students can watch a brief animated tutorial of the tools used in the modeling process (Figure 2b).

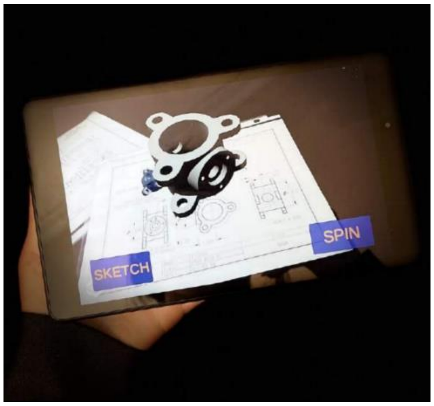

Figure 2a. AR Application tracking drawing

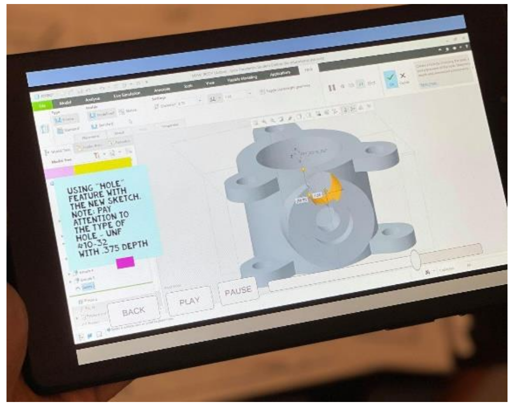

Figure 2b. AR Application tracking drawing

A total of 39 male and female (control group =19, independent group = 20) students from freshmen to sophomore levels participated in the study from different sections of CAD course with the same instructor. The independent group visualized the blueprint (Figure 3a) of the model with bare eyes and no phones were used. On the other hand, the control group observed the blueprint with the AR application (Figure 3b). In addition to the development of a 3D model, from its

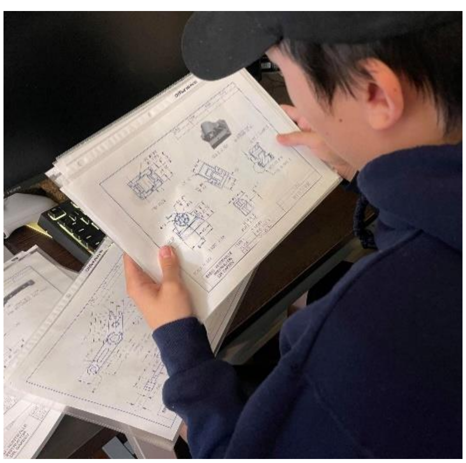

Figure 3a. Student participant observing the blueprint.

Figure 3b. AR application projecting the final product.

blueprint, both participating student groups completed a spatial cognition test (Dakeev et al., 2020) from 123.com independently (Figure 4) to investigate the effectiveness of the ARCADE.

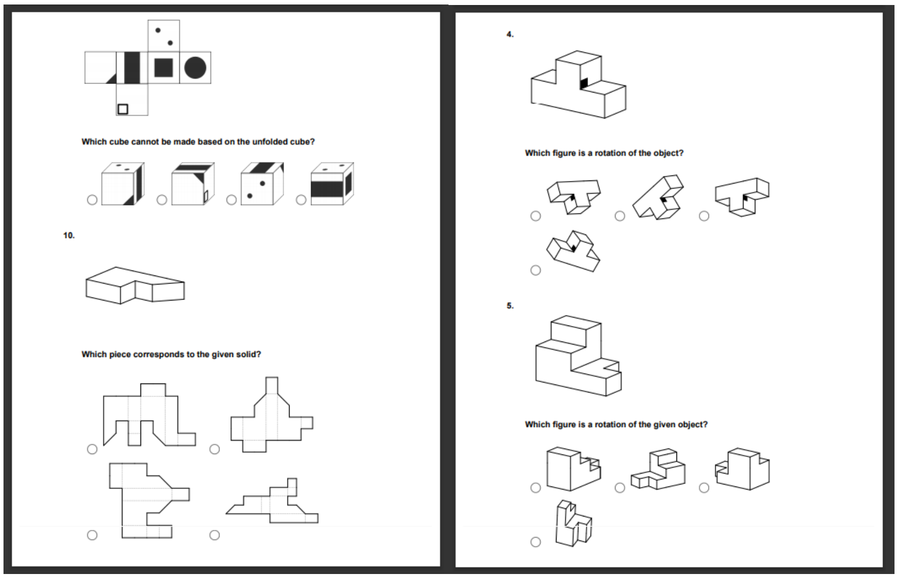

Figure 4. The spatial cognition test (Modified from 123.com).

The researchers conducted a paired sample t-Test to investigate how the AR application improves students' perspective after they had observed the blueprint. This test involved timing the students' overall understanding the blueprint in seconds.

Data Collection

An independent sample t-Test was conducted to compare means of the control and the independent groups in SPSS 22 for spatial cognition test (Figure 4). Descriptive statistics (Table 1) illustrates that the mean score of the control group (With AR) is 84.737, with standard deviation 10.73, and the mean score of the independent group (Without AR) is 68.500, with 14.964 standard deviation. Overall mean value of the control group (With AR=84.737- Without AR = 68.500=16.237) is higher than the independent group, that completed the test without the exposure to the ARCADE application.

Table 1: Descriptive Statistics for Participating Groups.

Group Statistics					
	Type	N	Mean	Std. Deviation	Std. Error Mean
Score	With AR	19	**84.737**	10.733	2.462
	Without AR	20	**68.500**	14.964	3.346

The two – tailed independent sample t-Test (Table 2) resulted that there is a significant difference (p=0.001< alpha =0.05) between the means of two groups (Mean control = 84.737> Mean independent =68.500). Therefore, these outcomes suggest that the use of AR application significantly improves spatial cognition of students in CAD courses.

Table 2: The Independent Samples Test

Independent Samples Test									
	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.647	.207	3.875	37	**.000**	16.237	4.190	7.747	24.726
Equal variances not assumed			3.908	34.477	**.000**	16.237	4.155	7.798	24.676

For paired sample t-Test analysis, total of 18 volunteering student participants, from various departments, observed the blueprints, while the researchers timed, until the participants completed, they inspection. Descriptives on Table 3 illustrates the mean scores between the paired groups, where the lower mean indicates faster comprehension of the illustrated part.

Table 3: Paired Samples Descriptives

Paired Samples Statistics					
		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	WithoutAR	79.777	9	36.591	12.197
	WithAR	46.222	9	11.530	3.843

Paired sample test (Table 4) illustrates that there is a significant difference between the two mean scores, where the first test (WithoutAR) entailed observing the provided blueprint with naked eye, the conventional method of teaching, and the second group (WithAR) illustrates the mean scores of the students that used the ARCADE application to visualize the final product.

Table 4. Paired Sample Test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	WithoutAR - WithAR	33.555	34.742	11.580	6.850	60.260	2.898	8.000	0.020

The outcomes of Table 3 and Table 4 suggest, with 95% confidence interval, that there is a significant difference ($p=0.02<0.05$ alpha level) between the two groups. Additionally, the time spent to understand the blueprint with the ARCADE application is significantly lower (Mean WithAR=46.222< Mean WithoutAR=79.777). Additionally, the researchers are providing the some of the student comments from the study. Student 1- "*What I was picturing it in my mind in 3D was totally different and the assembly animations make a lot of sense about how it functions. The AR was very explanatory to me, without this app, I would have had a lot of questions*". Student 2- *"The AR makes it easier to imagine the size and shape in general, and especially understand how the parts go together"*. Student 3 – *"I definitely missed out the hole that was enclosed, I thought that something can be pushed through it"*. Student 4- *"As an aspiring Geographer, I believe AR app definitely helps me to put the views together instead of just looking at the isometric view. However, if the dimensions can go with the model, it would be better to notify the actual size"*. Some of the collected comments, from students during and after the test, suggest that the use of ARCADE could not only be beneficial in understanding the overall blueprint for non-engineering majors, but also provides a blueprint friendly condition.

Summary and Conclusion

This study explored the effectiveness of Augmented Reality Computer Aided Design Education (ARCADE) application in student learning, engagement, motivation, and spatial cognition in CAD course. Paired sample and independent sample t-Tests resulted that ARCADE significantly improves the understanding of 2D blueprints and spatial cognition skills with or without prior 3D modeling experience. Additionally, the independent sample t-Test showed that the use of Augmented Reality tool significantly improves student understanding of 3D models. Moreover, users have commented positively on the concept on utilizing AR App in education, especially a CAD course. As learning engagement and motivation increases, the result of learning process can also be improved. Consequently, the researchers believe the use of AR applications in CAD and other courses may improve the student engagement as well as their motivation. This study will continue collecting more data in future CAD courses to validate this initial finding as well as conduct additional tests to statistically analyze the motivation and engagement through Motivational Strategies for Learning Questionnaire.

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