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Research Paper

The Effect of Augmented Reality on Achievement and Spatial Visualization Skills in Technical Drawing Course

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ABSTRACT

This study investigated the effect of using the technical visual arts lessons' material on visualization skills and attitudes. For this purpose, an augmented reality application called BTRS was designed. The application was created using Unity3D, 3Ds Max, and Vuforia programs. The study was conducted for eight weeks, with a total of 33 students (26 boys and seven girls) attending a vocational and technical high school. The study was designed based on Creswell's sequential explanatory design. While a semi-experimental method with a pretest-posttest control group was conducted for the quantitative part of the study, semi-structured interviews were used for the qualitative component. "Lappan Spatial Visualization Skill Scale," "Purdue Spatial Skill Scale," "AR Attitude Scale," and semi-structured interview form were used at the beginning and the end of the application. The Mann-Whitney U, paired-samples t-test, and the Wilcoxon signed-rank test were used for quantitative data. Qualitative data were analyzed by the descriptive analysis method. The study results indicated that the Augmented Reality Application did not significantly affect the achievement of the students and their spatial visualization skills. However, it has been observed that students' excitement and curiosity increased. The students reported that the material was enjoyable, fun, attractive, remarkable, helpful, easy to use, understandable, and persistent. Rotating, zooming, and moving interactive digital models and buttons in the real world have attracted the students. The experimental group described abstract concepts and required spatial thinking skills to be more explicit and more practical.

INTRODUCTION

Higher Education (HE) institutions and industry are concerned about the reduction in Technical Drawings (T.D.) standards as a result of a lack of awareness of essential principles and norms that underpin best practices (Huerta Cardoso, Unver, Aslan, Kus and Chotrov, 2019). Compared to traditional didactic techniques, there is rising evidence that simulations, animations, augmented and virtual reality (AR/VR) technology can improve learners' engagement, competence, and skills (Huerta Cardoso, Unver, Aslan, Kus and Chotrov, 2019). In general, spatial ability is the fundamental sensory talent for recognizing and comprehending physical objects (Salkind 1976). This ability is crucial in the study and training of several sciences, including chemistry, physics, mathematics, and engineering (Chen, Chi, Hung, and Kang, 2011).

It is necessary to allocate a high budget for materials such as prototypes, models, or posters in education. Often schools cannot afford to buy the learning materials they need. Moreover, these learning materials risk being worn out, losing interest, or being lost over time. On the other hand, traditional instructional approaches are discouraging and no longer pique the interest of kids. They are deemed monotonous and uninteresting, and they don't offer enough interaction (Oliveira and Silva, 2019). Young people are becoming increasingly interested in computers, games, and the internet. With augmented reality (AR) technology, there is no need to invest in such materials. Students can access the AR model at any time and from any device.

A recent systematic review (Garzon, Pavon, and Baldiris, 2019) results show that most AR technology studies were applied in natural sciences, mathematics, and statistics (49.2 %). It is followed by arts and humanities (16.4%) and social sciences, journalism and information (11.5%)—only 1.6% of the studies in the education field. Despite the fact that AR research and development has been driven by the needs of business-related enterprises rather than sectors involving education, and no specific agenda for AR technology has yet been established for educational purposes, academics and researchers have continued to look for practical ways to use the technology in education (Kaenchan, 2018). Researchers are confident that AR has potential implications for the augmentation of many teaching and learning contexts, given the capability of AR that makes user interfaces more intuitive and makes teaching abstract concepts easier. Abstract or complex concepts that are difficult to explain in the classroom could be brought to life with interactive, multimedia information that is more engaging for students using AR interface technology (Kaenchan, 2018).

According to Piaget's theory of cognitive development stages, K-12 pupils move from the concrete operational stage to the formal operational stage. Students who are just beginning their abstract thinking stage, according to Piaget (1976), have difficulty understanding this type of material (Gün and Atasoy, 2017). Students' spatial abilities should be enhanced to overcome such challenges in technical drawing course. Some previous research looked at the link between achievement and spatial ability. Their mental construction and maintenance of pictures, their perception of objects from various perspectives, and their rotation and shifting of shapes in their minds are all examples of these talents (Linn & Petersen, 1985; Lohman, 1996). Though there is no precise consensus on the components of spatial ability, the two basic elements, spatial visualization and mental rotation, are generally agreed upon. Some research links spatial abilities to higher-level skills like problem-solving and reasoning, which can be improved by training (Kaufmann, Steinbügl, Dünser, & Glück, 2005). The development of spatial ability is aided by activities such as building with Legos, making technical drawings, and following directions (Kurtuluş and Uygan, 2010; Huang and Lin, 2017).

AR technology can be used on various platforms, including desktop and mobile. However, in today's world, mobile Augmented Reality (MAR) has been shown to be a beneficial tool for educators and students. Research indicates that AR technology has a lot of potential for increasing student engagement and understanding of the learning content. As a result, mobile technologies in education must be adopted because of their potential to interest and motivate students during the learning process (Omar et al., 2019).

A technical drawing is a communication tool that directs the appropriate personnel at every stage of a product's or structure's development, manufacture, or building, as well as marketing and use. Balak and Kısa (2016) describe it as "a technical alphabet of delivering the easiest and most accurate communication among engineers." Technical drawing is a discipline of science that graphically portrays the shape and dimensions of an object. It also includes all of the methods used to solve space problems graphically. The primary goal of the technical drawing course is to teach students how to think, ask questions, and apply their knowledge. This course's "Expansions" subject is an analytical and visual subject that students cannot grasp (Mendi, Toktaş, & Karabıyık, 2004).

There are various classifications of spatial ability. Spatial visualization is defined as one of the most critical sub-dimensions of spatial ability (Yüksel & Bülbül, 2014). In some studies, it is seen that the concepts of spatial ability and spatial visualization skills are used interchangeably. McGee (1982) defined spatial visualization as a subset of spatial skills as "the ability to mentally manipulate, rotate, twist, or invert a stimulant object represented by a picture." Fennema and Tartre (1985) defined spatial visualization as "spatial ability tasks that require complex multi-step manipulations of spatially represented information." Olkun and Altun (2003) defined spatial visualization as the ability to visualize new situations that will occur due to moving 2-dimensional and 3-dimensional objects and their parts in space.

The purpose of this study is to see how AR application use affects students' spatial visualization skills, academic achievement, and attitudes in the 10th-grade Informatics Technical Drawing course at Anatolian Vocational and Technical High Schools. In this context, the following research questions were identified:

1. What is the effect of Augmented Reality applications on the academic success of students?
2. What is the effect of Augmented Reality applications on students' spatial visualization skills?
3. What are the students' attitudes towards BTRS material?

METHOD

Creswell's (2003) sequential explanatory model, one of the mixed method designs, was used in the study. While a semi-experimental design with a pretest-posttest control group was used for the quantitative part of the study, the semi-structured interview method was used with the students selected voluntarily from the observation and experimental group in the qualitative part.

Research Design

The experimental process was conducted on the subjects of "Projection" and "Appearance Removal" in the Informatics Technical Drawing course in the Fall semester to examine the effects of using the AR -based mobile application in the study. The experimental process investigated whether the AR application named BTRS, which the researcher designed, affected the students' academic achievement, spatial visualization skills, and attitudes towards the material. In this process, the course teacher taught the course with the control group using the demonstration and practice method only through the coursebook. The teacher in the experimental group used the BTRS material when it was stated in the lesson plan while teaching the subjects from the coursebook with the demonstration and practice method.

Prior to the experimental process, the spatial visualization skill scale and the spatial rotation skill scale were applied to both groups as a pretest. The 1st exam grade point averages of the experimental and control groups in the Informatics Technical Drawing course in the fall semester were considered as the academic achievement pretest. BTRS application was used for eight weeks with the students in the experimental group. At the end of the experimental process, the academic achievement test, spatial visualization skill test, and spatial rotation skill test were applied to all groups. An attitude questionnaire for the BTRS material was applied to the experimental group.

Participants

A total of 33 students, seven girls, and 26 boys, studying at the 10th grade level of Vocational and Technical Anatolian High School Information Technologies constituted the study group of the research. Core courses in vocational high schools in Turkey are taught in workshops or laboratories. The class is divided into two or three groups according to their size. In the school where the study was conducted, 10th-grade students of Information Technologies were split into two groups in the core courses. Among the existing groups, the experimental and control groups were randomly assigned. Convenience sampling is a method that accelerates the studies (Şahin, 2017). Therefore, the researcher preferred the students from the school where she was working and determined the study groups by convenience sampling. According to the results of the analysis applied to all pretest data applied to the groups, it was determined that the experimental and control groups were equivalent.

Data Collection

The data collection tools used in the study were “Lappan Spatial Visualization Test," “Purdue Spatial Visualization Skill Scale," “Academic Achievement Test," “AR Attitude Questionnaire,” and “Augmented Reality Student Interview Form.” While the researchers prepared the Academic Achievement Test, other scales were taken from the literature. Lappan Spatial Visualization Test was developed by Ben-Chaim, Lappan, and Houang (1986) for use in the “Middle Grades Mathematics Project” carried out by the Michigan State University Mathematics Department to measure students’ spatial skills. It includes two examples with solutions at the beginning of the scale questions. It contains 32 multiple-choice questions with five items. Purdue Spatial Visualization Skill Scale was developed by Guay (1977). The test includes questions about 3-dimensional surface models created by folding a two-dimensional flat pattern. It consists of 30 multiple-choice questions with five items to measure the ability to rotate a 3-dimensional object in mind. At the beginning of the scale, there is an example with a solution and instructions. Academic Achievement Test, prepared by the researcher, one of the course teachers, and the other teacher teaching the course, includes five drawing applications and ten questions to define abstract concepts. The models used in the questions were taken from the coursebook prepared by Bereket and Tekin (2017). The questions were created by taking into account the achievements of the units covering the course content. The Augmented Reality Attitude Questionnaire was developed by Küçük, Yılmaz, Baydaş, and Göktaş (2014) to determine secondary school students’ attitudes towards using AR applications in education. The augmented questionnaire has three factors: ‘satisfaction with use,' ‘anxiety for use,’ and ‘desire to use containing 15 questions in 5-point Likert type. Augmented Reality Student Interview Form prepared by Baysan (2015) was used in the study. A total of seven questions were asked to determine students’ opinions about the developed material and the technology used. The questions included the views about the AR material used in the lesson, the difficulties and deficiencies encountered while using the AR material, the contribution of 3D objects used in AR material to learning, the reasons for preferring the AR material, and the advantages and disadvantages of using the AR material in education.

Experimental process of the research

An AR -based educational material (BTRS) was developed to support the Informatics Technical Drawing courses given in information technologies or the Technical Drawing courses given in the field of electrical-electronic technologies at the 10th grade level of Vocational and Technical Anatolian High Schools. BTRS includes the ‘Projection’ and ‘Appearance Removal’ units of the Fall semester in the annual plan. Three teachers brainstormed before these units were preferred. Within the scope of this course, these units were chosen because they are time-consuming subjects in learning, and students have difficulty comprehending and teachers in transferring. The coursebook Informatics Technical Drawing prepared by Bereket and Tekin (2017), approved by the Information Technologies field management, was used in the content part of the material. The developed material was named BTRS, inspired by the abbreviation name of the course. Material design principles were taken into account while designing the BTRS application.

Pilot Implementation and Elimination of Deficiencies

Before the main study of the BTRS application, a pilot study was planned to prevent potential problems. Before the pilot and the main study, permission was obtained from the parents of all students to be included in the experimental process. Furthermore, ethics committee approval was also obtained. A two-week pilot study was conducted with a total of 15 students in a different Vocational and Technical Anatolian High School located in the same district as the school where the main study was planned. The “projection of the point” subject was taught in the first week of the pilot study, and the “places of appearances-1” subject was discussed in the second week. Some problems were identified during the pilot study. Solutions for these problems were developed before starting the main study. The following are the issues that were encountered and their solutions:

- The fact that the coursebook pages could be taken apart one by one made it easier for the paper sheet to be rotated around itself. Students were given files to eliminate the chance of pages being misplaced.
- There was a problem detecting the images used as the target image (marker) taken from the coursebook in the application’s camera. This problem was solved by increasing the contrast and saturation values of the target images (marker).
- The images turned out dark due to insufficient light in the classroom environment while using the application with the pilot experimental group. The blurring of the images on the camera screen caused the target images (marker) not to be detected. The focus event was added to AR Camera with a C# script as a solution to it.
- Because the goal of the application was not clear when it was shared with the pilot experimental group students, students were given more information on “What is AR and what is the goal of the BTRS application, how is it used?” and BTRS was demonstrated in practice.

- It was observed that the weekly subjects were not taught in parallel since the course teachers of the pilot experimental and control groups were different. To prevent it in the main study, the course teachers came together and prepared the united lesson plan of the subjects and activities suitable for BTRS supported teaching for each week.
- It was discovered that some students fell behind in class because they forgot or misplaced their coursebooks. A student from each group was assigned to address these problems. The assigned students collected the coursebooks at the end of the lesson and locked them in the laboratory cabinet. Before the class started, they took them from the cabinet and distributed them to their owners.

Main Study

The experimental process was carried out with 10th-grade students of Information Technologies of a Vocational and Technical Anatolian High School. A total of 33 students, 17 students in the experimental group and 16 students in the control group, participated in the study. The experimental process included the 'Projection' and 'Appearance Removal' units of the Informatics Technical Drawing course. According to the annual course plan, these two units were supposed to take eight weeks. The study was carried out for 16-course hours, 2-course hours per week. Spatial visualization skill tests were applied to all groups as a pretest before the experimental process started. The experimental group was given an orientation program to inform them about the study and the BTRS application.

Teachers in both the experimental and control groups made sure to stick to the 8-week united lesson plan created in the pilot study. The course was taught face-to-face with the students in the control group using the existing coursebook and the demonstration and practice method. The courses were taught utilizing the BTRS AR application, the mobile learning approach, and the demonstration and practice method with the students in the experimental group. Both groups participated in weekly activities on a regular basis. Some of the examples of the AR -based BTRS application are presented in Figure 1.

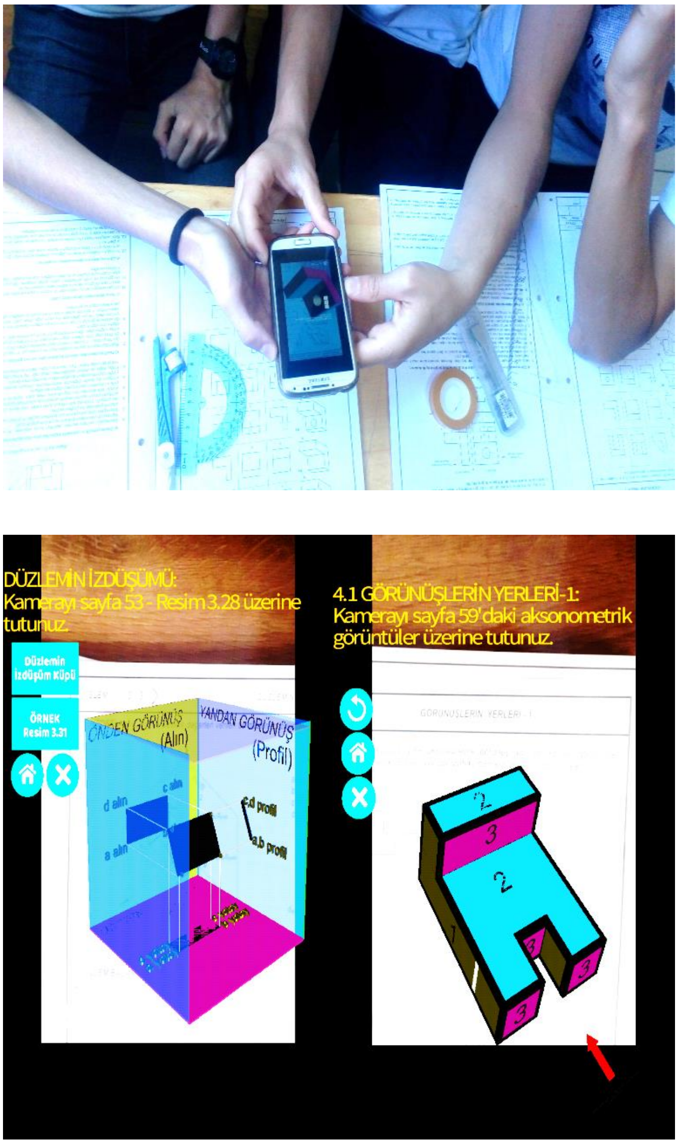

Figure 1. The examples of the AR-based BTRS application

Data Analysis

The comparison of the pretest and posttest results of independent experimental and control groups refers to the measurement of unrelated samples. The comparison of the pretest and posttest results of either of the experimental or control groups refers to the repeated measurement for related samples (Büyüköztürk, 2016). With the study's quantitative data, both unrelated samples t-test and related samples t-test were performed.

Before the data analysis, the Shapiro-Wilk Normality Test was run. The data were normally distributed, and the Levene Test showed that the variances of the groups were homogeneous. However, as a result of the normality and homogeneity tests, it was concluded that the conditions for the two-score types were not met. Non-normally distributed Purdue posttest data, and non-homogeneous Purdue pretest data were analyzed with Mann-Whitney U test and Wilcoxon signed-rank test.

Focus group interviews were conducted with six students who volunteered from the experimental group. Furthermore, six students who could not participate in the interview were asked to fill out the interview form in writing. Thus, the researchers collected 12 students' opinions about BTRS. In the study, descriptive analysis was performed on the qualitative data obtained from the interview form and the interviews. Researchers followed four stages during the descriptive analysis: coding of the data, finding the themes, arrangement of codes and themes, and description and interpretation of the findings.

A field specialist was given a codebook with the codes and their definitions, and he was asked to code the data. The interrater reliability of two independent raters should be calculated with Cohen's Kappa coefficient (Can, 2017). After the field expert coded the data, Cohen's Kappa coefficient was calculated to determine the reliability coefficient. As a result of the calculations, Cohen's Kappa coefficient value was found to be .645. The Cohen's Kappa coefficient calculated showed a good fit between the two codings. [K=0.645, p<0.01].

FINDINGS

Findings Related to Academic Achievement

Table 1 shows the pretest-posttest results of the experimental and control groups. When they were compared, there was no significant difference between the mean posttest scores of the control group (x1=58.5) and the experimental group (x2=64.2) in terms of the effect of using AR -based BTRS application as supplementary educational material in the Informatics Technical Drawing course in terms of academic achievement [t(31) = -0.928 and p=0.361 > 0.05]. According to the Lappan test results, there was no significant difference in the effect of using AR -based BTRS application as supplementary educational material in the Informatics Technical Drawing course on students' spatial visualization skills between the mean posttest scores of the control group (x1=6.1) and the experimental group (x2=5,6). According to the Purdue posttest results, there was no significant difference between the experimental and control groups (U=112.5 and p=0.394 > 0.05).

Table 1. Pretest-posttest scores according to academic achievement, Lappan and Purdue Scale

		N	Mean	sd	df	t	p
Academic achievement pretest	Control	16	60.50	16.21	31	1.30	0.20
	Experimental	17	51.26	23.52			
Academic achievement posttest	Control	16	58.56	17.62	31	0.92	0.36
	Experimental	17	64.23	17.48			
Lappan pretest	Control	16	4.93	1.91	27	0.76	0.45
	Experimental	13	5.46	1.76			
Lappan posttest	Control	16	6.18	1.10	30	1.28	0.21
	Experimental	16	5.62	1.36			
Purdue pretest	Control	16	13.43	2.70	29	2.46	0.020
	Experimental	15	9.93	4.96			
Purdue posttest	Control	16	12.06	3.37	31	0.12	0.90
	Experimental	17	11.88	4.67			

There was no significant difference between academic achievement scores and Lappan spatial thinking skill scores in the experimental group in which it was investigated whether the use of the BTRS application had a significant effect on students' spatial visualization skills [t=-0.305, p=0.766 > 0.01] (Table 2).

Table 2. The pretest and posttest relations of the experimental group

	N	$\bar{x}$	S	sd	t	p
Academic achievement pretest	17	51	23.5	16	-2.71	0.015
Academic achievement posttest	17	64	17.4			
Lappan Pretest	13	5.4	1.76	12	-0.305	0.766
Lappan Posttest	13	5.6	1.38			

In the experimental group in which it was investigated whether the use of BTRS application had a significant effect on students' spatial visualization skills, no significant difference was observed between academic achievement scores and the Lappan spatial thinking skill scores [t=-0.305, p=0.766 > 0.01] (Table 3). No significant difference was observed in the experimental group in which it was investigated whether it had a significant effect on spatial rotation skills [z=-0.275, p=0.784 > 0.05].

Table 3. Pretest-posttest results in terms of Purdue Spatial Visualization Skill Scale scores

Purdue Pretest - Posttest	N	Mean Rank	Rank Sum	z	p
Negative Ranks	6	5	30	-0.275	0.784
Positive Ranks	5	7.2	36		
No Difference	2				

Findings Related to Attitude

Twelve students answered the student interview form prepared to measure student attitudes towards BTRS. As a result of the qualitative data analysis, 28 codes were created under seven questions and are presented in Table 4.

Table 4. Interview Coding

Order of Questions	Codes
1	Effective Learning, Visuality, Ease of Perception, Excitement.
2	Lack of Hardware, Software Inadequacy, Difficulty of Use, Attention Deficit.
3	Distinctiveness, AR Object Types, Interaction.
4	Amusing, Efficient, Useful.
5	Physics, Chemistry, Biology, Mathematics/Geometry, Geography.
6	Convenience, Lack of Commands for Interaction.
7	Military, Architecture, Advertising, Plumbing, Automation.

As a result of the descriptive analysis of the data obtained from the students' opinions, it was revealed that students learned more effectively with visual elements and that 3D models facilitated perception and also gave pleasure. Miray stated that "AR application gave us an opportunity to work on objects visually and provides more memorable learning," while Ayse noted that "I liked seeing the projection cube and the images of any object in it like point, line, plane or object falling onto the cube's surfaces." Arda stated that "opening and closing the projection cube with animation helps to understand the concept of epure plane more clearly." It was revealed that some hardware and software technical problems experienced while using the mobile application led to distracting students. The students felt inferior since those who did not have the Android operating system or a mobile device was at a disadvantage. Mirac stated that "We shared Baran's phone to use AR application at the school, but I couldn't use it at home, because my phone doesn't have android system. I wish me or my family had such a phone."

It was concluded that the 3D models in the BTRS application facilitated perception and contributed to distinguishing complex shapes. All of the students reported that they found the application amusing. They recommended AR -based applications, especially in courses where three-dimensional models are used or visual elements are needed. Emre said that "In a project prepared for the geography lesson, they showed the layers of the mountain through the image projected on the sand pile. If we had AR app in our smartphone, we would re-examine the project outputs whenever we wanted." Students thought that the AR application provided a lot of conveniences, especially for the teacher. They considered that different ways of interaction would make the application more amusing while interacting with 3D models. They state that the concepts that have to be explained at length in the class can be demonstrated very easily by turning on the application, making the course more effective.

CONCLUSION AND DISCUSSION

Effect of BTRS Application on Students' Academic Achievement

The academic achievement test was conducted at the end of the 7-week education plan for the experimental and control groups, and no significant difference was found between the groups' academic achievements. This result indicates that BTRS, which was developed as supplementary material for the coursebook, was not effective enough to make a significant difference in students' achievement. Nonetheless, this finding does not rule out augmented reality applications as supplemental material in the classroom. Because this course has a low cognitive load due to its content and students succeed without difficulty. When the mean academic achievement scores of both groups were examined, it should not be forgotten that there was no significant difference. However, the mean pretest score of the experimental group in the fall semester was lower by 9.3 points compared to the control group, and the posttest result was higher by 5.7 points. In the annual plan, course contents are planned from simple to complex. In this context, considering the periods during which the mean achievement scores were taken, the mean score of the experimental group was quantitatively lower in more straightforward subjects and closed the score gap in complex subjects and was over the control group. It was considered that the BTRS application affected this success.

The findings on academic achievement are consistent with the results of previous research in the literature that investigated its impact on student achievement. Akkuş (2016) used the AR application in the Computer-Aided Technical Drawing course and measured the students' academic achievement. He did not find a statistically significant difference in the technical achievement scores of the experimental group and the control group, and he also did not find a significant difference in the weekly measurements of the groups. This result is in parallel with the studies conducted in the literature. Gün (2014) used AR application in geometry lessons to examine its effect on academic achievement. He did not find a statistically significant difference between the experimental and control groups students. Baysan (2015) examined the impact of the AR application he designed on computer hardware on students' academic achievement, and he also did not find a significant difference. As a result of the study carried out with the mobile AR activities used in the secondary school Biology course, Erbaş (2016) concluded that there was no significant difference between the academic achievement scores of the experimental and control groups. İbili and Şahin (2013) used the AR application in the mathematics course and indicated that its effect on the students' academic achievement was not statistically significant. Garzon and Acevedo (2019) looked over 64 empirical publications to see how AR affected students' academic achievement and discovered that it had a 0.68 effect size on average. Within their study, they explained the influences that moderators of AR such as learner grade levels and domain subjects have on the learning gains. Previous research has established AR application methodologies for K-12 education and confirmed that AR may increase students' academic achievement in science, mathematics, and other topics through teaching experiment research (Herold, 2014; Sil et al., 2014; Tilhou, Taylor, & Crompton, 2020). According to Sommerauer and Müller's (2018) findings, AR learners' academic achievement was significantly higher than that of non-AR learners in the short term, but this positive effect of AR faded with time.

Effect of BTRS on Students' Spatial Visualization Skills

When the effect of the BTRS application on students' spatial visualization and spatial rotation skills were examined, our results showed no significant difference between the experimental and control group students. Our result is similar to the studies conducted in the literature. As a result of the AR application used by Akkuş (2016) in the Computer-Aided Technical Drawing course, no significant difference was observed between the spatial achievement scores of the experimental group and the control group in which printed paper was used. However, the researcher's observation notes reported that the experimental group students verbally expressed the abstract concepts with correct terms more clearly and quickly. It was observed that students who encountered the abstract concepts of the course content of BTRS for the first time learned more effectively, accurately, and quickly because it visualized the patterns that were anticipated to be visualized in their minds. It is a fact that the inclusion of 3D models in the BTRS application piques students' interest and curiosity about the content, increasing their attention to the course. The active participation time of the students who turn their attention to the course also increases. The literature indicates that the use of 3D objects in educational materials and the fact that students can examine these objects 360 degrees provide them with the experience of learning by doing and living. Therefore, it is stated that students' learning is more effective and permanent (Chen, Chi, Hung, and Kang, 2011; Wojciechowski and Cellary, 2013).

Students' Attitudes towards BTRS

The responses to the student interview form and the observation data were used to determine students' attitudes towards AR -based BTRS. It was observed that students' attitudes towards the application were generally positive. The fact that the course material could be accessed anytime and anywhere, the visualization of abstract concepts, especially in 3D, and their opportunity to interact with 3D objects were among the factors that positively affected students' attitudes. This result is parallel with the studies conducted in the literature (Abdüsselam and Karal, 2012; Özarslan, 2013; Gün, 2014; Sırakaya and Alsancak Sırakaya, 2018; Garzón and Acevedo, 2019). Students defined their favorable attitudes using words like amusing, engaging, interesting, remarkable, useful, easy to use, catchy, and I understood better.

The AR technology benefits teachers in conveying the abstract and complex information in the course content and to students in imagining and placing it in the schemas in their minds (Balak and Kısa, 2016). In the literature, it has also been concluded that the AR technology makes it easier for students to understand the subjects (Gün, 2014; İbili and Şahin, 2013; Núñez et al., 2008; Shelton and Hedley, 2002).

Students' observations suggested a high level of curiosity about new technologies. Students were enthralled by the idea that AR could be used on mobile devices and integrate three-dimensional models and animations into the actual environment. They were able to stay motivated for the course for a longer amount of time because they attempted to investigate the topic of the course while using the material. Previous research also indicated that AR quickly draws the attention and care of students and increases their motivation for the course (Delello, 2014; Fleck and Simon, 2013; İbili and Şahin, 2013; Kerawalla et al., 2006; Küçük et al. 2014; Perez-Lopez and Contero, 2013; Tomi and Rambli, 2013; Yen, Tsai and Wang, 2012). The fact that they were interacting with 3D objects and buttons, and the operations such as rotating, zooming in and out, and enlarging and reducing them increased the sense of reality and attracted students' attention. AR applications are attention-grabbing for students due to the transformation of the objects (Bujak et al., 2013; Wojciechowski and Cellary, 2013; Abdüsselam and Karal, 2012). They eliminate the possibility of teachers making incomplete or unrealistic drawings on the board while showing them in the course-book, preventing misconceptions (İbili and Şahin, 2013). Their desire to share the qualities they discovered during their interaction with AR supported objects with their peers and helped each other at the point where they were lacking increased their cooperation power. The students' attempts to use the app after school created a door for them to refresh and repeat their course knowledge after the lecture. According to the students in the experimental group, AR application and activity sheets became a tool for reviewing the course that they could use both during and after the class. However, there is another critical point regarding using the mobile application by students outside of course hours.

It was observed that students who did not have a mobile device or whose mobile device's operating system did not support this application were disadvantaged. Therefore, it will be beneficial to use mobile technologies as supplementary material, not as the primary material of the course, to ensure equality of opportunity.

The repetition of the abstract concepts and terms, which are frequently used in projection and appearance removal units, provided through concretization for their first experiences, increase permanence in students' minds. Because AR objects allow students to readily concretize abstract material in their minds and absorb subjects much faster, more time may be dedicated to the lesson. (İbili and Şahin, 2013). It was considered that with the AR application offering the opportunity to be used continuously, it met these requirements and positively affected students' achievement. It is also indicated in the literature that such applications can be used as an effective material in the learning environment (Abdüsselam and Karal, 2012; İbili and Şahin, 2013; Baysan, 2015; Gün, 2014; Erbaş, 2016; Küçük, et al. 2014; Fleck and Simon, 2013; Matcha and Rambli, 2013; Núñez, et al. 2008; Perez-Lopez and Contero, 2013; Tian, et al., 2014). An efficient learning process took place depending on the use of these materials. Mayer, Fiorella and Stull (2020) stated that the list of evidence-based principles for learning with various multimedia applications must be expanded, which is especially true for technologies like AR and IVR.

RECOMMENDATIONS

The use of AR technology to enhance the design of technical drawing course books with 3D models and animations will make the course more fascinating, enjoyable, and understandable. In this situation, technical drawing classes at all education levels can be tailored to cover all units, not only projection and appearance removal. There is a problem with the model since there is a need for qualified designers to design realistic 3D models suitable for the course content, and the design process requires a significant time interval. A content library can be created with the prepared models to contribute to the technology integration projects. In addition, the inclusion of game-based exercises to support the lectures in the educational material will make the application more interesting and fun. The selection of real-life images or models and the high sense of reality in the AR -based mobile applications planned to be designed will increase the interest in the material. The methods of giving commands not only by touching the object but also by voice, eye, and power of thinking can be developed for students to interact with 3D models. There is a need for new curriculum development studies to be used with appropriate teaching approaches by considering the course's objectives, specifically for courses in other disciplines.

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