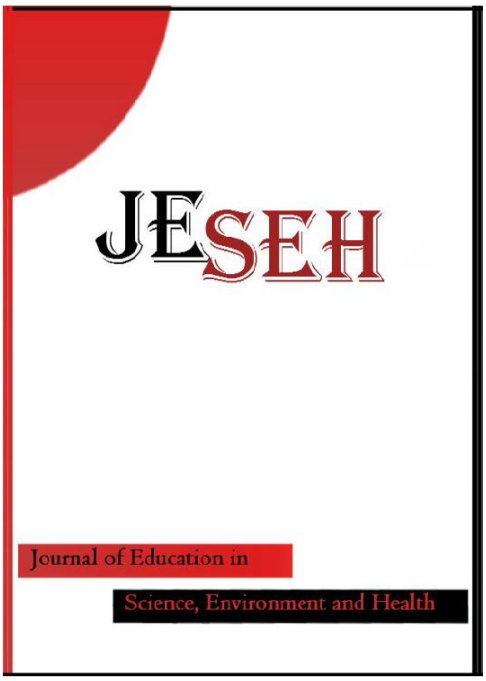

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Ismet Yildirim[1], Munise Seckin-Kapucu[2]
[1]Ministry of National Education
[2]Eskisehir Osmangazi University

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The Effect of Augmented Reality Applications in Science Education on Academic Achievement and Retention of 6th Grade Students

Ismet Yildirim, Munise Seckin Kapucu

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Abstract

The role of technology literacy in education, which is one of the 21st century skills that students should have, is very important. This study examines the effect of augmented reality (AR) applications, which is a new technology, on students' academic achievement and the level of recalling the learned knowledge. In this study, quasi-experimental design with pretest-posttest control group, one of the quantitative research methods, was used. The study was carried out with a total of 50 students, 24 in control and 26 in experimental groups, studying in the 6th grade of a secondary school in the Odunpazarı district of Eskisehir. The study lasted for 9 weeks, covering the Solar System and Eclipses unit and the Systems in Our Body unit of the 6th grade Science curriculum. During the process, the lessons instructed in the experimental group (EG) were supported by AR applications, whereas only the textbook was used in the control group (CG). The tools used in data collection were "the Solar System and the Systems in Our Body achievement test", developed by the researcher and a semi-structured interview form for AR applications. Independent samples t-test, covariance analysis (ANCOVA) and descriptive analysis were used in the analysis of the data obtained from the achievement test. Content analysis was used in the analysis of the data obtained from the interview form. As a result of the research, it was observed that the use of AR applications in the processing of the course was effective in increasing the academic success of the students in the EG and in the permanence of the information they learned compared to the students in the CG, who only used the textbook. In addition the following findings were revealed: students have not used AR applications before, these applications were effective in increasing the academic success of the students, the knowledge that they have learned was permanent mostly because of the 3D feature of the technology, the applications worked smoothly and it may be useful to use them in other courses. Based on these results, it is suggested to use AR applications more frequently and actively in all topics of science and in all grade levels of secondary school.

Introduction

Today, where the greatest power is knowledge, societies are shaped on the use, production and teaching of knowledge, which is a product of science. Knowledge obtained as a result of scientific studies creates new perspectives and new horizons. Technology is the biggest supporter of scientific studies. Science and technology, which constantly interact by contributing to each other, continue their development at full speed. In the 21st century, creative, innovative, entrepreneurial, flexible, responsible, information and technology literate individuals are needed. Partnership for 21st Century Skills [P21], 2013 classified 21st century skills under three headings: learning and innovation skills (creativity and innovation, critical thinking and problem solving, communication and social interaction), life and career awareness (flexibility and adaptability, entrepreneurship and self-management, social and intercultural skills, leadership and responsibility), and information media and technology skills (information literacy, media literacy, and information and communication technologies). Information, media and technology literacy are the prominent skills of this study. When it comes to raising 21st century people, we cannot think of education separately from technology. Science and technology which determine the level of development of societies (Karasar, 2004) are an integral part of education. The countries developed in the fields of science and technology are known to be developed in education systems as well. Hence, many countries, especially developed countries, have conducted studies on the use of technology and projects in education (Pamuk et al., 2013).

The inclusion of technology in education and being used by teachers and students provides better quality learning (Cakir & Yildirim, 2009). As it is known, the realization of learning in classical classroom settings is very difficult. With the contribution of technology, these difficulties in learning environments disappear to a large extent, if not completely eliminated. In order to provide more effective learning environments, new teaching strategies, methods, techniques, tools, materials or technologies that activate student, prevent distraction, make the topics interesting and fun are needed (Arici, 2013).

New technologies that we encounter as virtual reality (VR) and augmented reality (AR) are used in learning-teaching settings in education. These technologies emerge as a topic that attracts attention in education, becoming widespread and accepted. Computers, mobile phones, interactive whiteboards, videos, multimedia applications, educational games and learning platforms, simulations, VR, Internet and Web 2.0 applications are some examples of technology that are effectively used by teachers and students in educational settings (Dror, 2008). AR technology is one of the new educational technologies. AR is one of these new technologies, which has been increasingly used with the development of technology, and whose impact on education is widely discussed (Kucuk et al., 2014). The advantage of this new technology is creating a realistic simulation and experimental setting (Abdusselam, 2014). According to Azuma (1997), AR is a derivative of VR. He describes it as the settings built on the real world and supported by VR, rather than a purely virtual environment. More generally, AR is the interpretation and presentation of virtual objects placed in predetermined places on the image of the real world taken by camera by the computer programs (Yilmaz, 2014). Technology, which goes into every area of our daily life, is becoming more and more indispensable with a new development every day. AR, which is one of the new products of technology, also appears in new areas day by day. According to Azuma (1997), AR technology consists of at least six classes: medical imaging, maintenance and repair, explanation, robot route planning, entertainment, military aircraft navigation and targeting. Today, new fields, such as architecture, tourism and education, are added to these fields. Thanks to the rapid information transfer it provides, AR gains considerable potential in the areas it is used. Considering this knowledge transfer in the field of education, it will have a very positive contribution to education. AR technology will eliminate many obstacles in education with the opportunity to interact with virtual objects on the real world that it provides to its users. It is undoubtedly accepted that the application of technological innovations in education will increase the quality of education. Regarding the recent years in the Horizon reports, which are published regularly every year, AR technology is stated to be beneficial in education. AR technology provides diversity and makes it possible to interact on it. However, the use, acceptance and dissemination of educational technologies are more difficult and time consuming than other methods (Parker & Heywood, 1998). Therefore, the development of guiding materials to teachers for the use of programs such as AR it is important (Aktamis & Arici, 2013). AR is also very effective in developing some features expected from students, such as problem solving, group work, multi-faceted evaluation and understanding of different perspectives (Sahin, 2017). At the same time, it increases the academic achievement of students by extending their focus time (Abdusselam & Karal, 2012). At this point, the development of AR applications that have an important potential and apply them in education will be beneficial (Somyurek, 2014).

The use of educational technologies in addition to teaching materials in science lessons was reported to help students to relate the knowledge they have learned to daily life and to learn technology (Akpinar et al., 2005). The role of technology in science education is bigger than other fields. Technology can be used effectively in other fields as well but regarding the role of AR in science education, it can be said that it has an important potential thanks to its ability to concretize abstract concepts. AR applications not only concretize abstract concepts, but also provide an opportunity to experience the settings that are difficult to access or cannot be created on the world. From this point of view, the effects of AR technology on students in science class are wondered. Educational technologies provide in-depth learning by concretizing abstract concepts especially for primary school-age children since they have difficulties in learning abstract concepts (Akpinar et al., 2005). For this reason, this study targeted the students who are at lower grades of education. On the other hand, the literature review revealed many studies on AR, the majority of them measuring the academic success of students and their attitude towards science course. In this study, it is aimed to investigate the effect of AR applications in science education on the level of recalling the learned knowledge of 6^{th} grade students. For this purpose, the following questions were addressed.

- Is there a significant difference between experimental group (EG) students' pretest and posttest achievement test scores?
- Is there a significant difference between control group (CG) students' pretest and posttest achievement test scores?
- Is there a significant difference between EG and CG students' average posttest scores adjusted according to pretest scores?

- Is there a significant difference between EG and CG students' average recall test scores adjusted according to posttest scores?
- What are the opinions of the EG students about AR applications?

Method

Research Model

In this study, quasi-experimental design with pretest-posttest control group, which is one of the quantitative research methods, was used to determine the effect of AR applications in science teaching on the level of recalling the knowledge. Fraenkel et al. (2012) summarized the main idea of all experimental research as "try something and systematically observe what is happening". The objective of the experimental studies is to test the cause-effect relationship between the variables (Buyukozturk et al., 2009). Experimental patterns can be divided into two, as multi-subject patterns and single-subject patterns (Buyukozturk et al., 2009). Fraenkel et al. (2012) divided the multi-subject designs into four as weak experimental designs, real experimental designs, quasi-experimental designs and factorial designs. Quasi-experimental design is the preferred experimental design in educational studies, when it is impossible to control all variables (Cohen et al., 2007). In this study, quasi-experimental design was used because all variables could not be controlled.

Study Group

The research was carried out with a total of 50 students, 22 girls and 28 boys, who were attending 6th grade of a secondary school in Eskisehir city center during the fall semester of the 2019-2020 academic year. In order to provide speed and convenience to the research, the sample was selected according to easily accessible criterion. In order to prevent the ongoing education process from being interrupted, control and experimental groups were not created artificially but were formed from existing students. While determining the control and experimental groups, the two classes which are academically similar among the 6th grades, with the most skillful class teacher in terms of using technology and which are more enthusiastic about working together, were chosen. The parental consent of a total of 7 students, 5 from the EG and 2 from the CG, could not be granted. These students are included in the study process in order not to violate their educational rights, but the data collected from these 7 students were not included in the data set.

Research Process

The research was planned to include the first two units of the 6th grade; the Solar System and Eclipses, and the Systems in Our Body units. The gains and concepts that cannot be acquired through AR applications are excluded from the study. After the necessary permissions were obtained from the Provincial Directorate of National Education and the Ethics Committee, the study was initiated with a total of 50 students, 22 girls and 28 boys, in the fall semester of the 2019-2020 academic years. At the beginning, the pretest was administered on both the control and experimental groups that we randomly determined. The study was planned according to the time intervals of the gains covered in the 6th grade science curriculum that are suitable for the study and lasted for a total of nine weeks. Two weeks of these nine weeks were involving the filling of the pre-test, post-test and interview forms. "The Solar System and the Systems in Our Body Achievement Test" was administered on the control and experimental groups as the pretest. During the study, Space 4D, Space 4D +, Virtual Teacher 4D, Our Body 4D, Luke AR, and Human Anatomy 4D AR applications and cards were used in the EG. During the study process, the researcher installed AR applications on the phone and tablet and actively used them. In addition, students who have a smartphone or tablet were asked to bring their devices to the lesson and AR applications were installed on the devices and made ready for the lesson.

Regarding the Solar System and Eclipses unit, two activities were carried out in the EG. The topics and concepts of this unit related to solar system, planets, meteor, blue stone, and asteroid were instructed using AR applications such as Space4D +, Uzay 4D, Sanal Ogretmen 4D. These activities targeted the following gains: "compares the planets in the solar system with each other." and "creates a model by sorting the planets in the solar system according to their proximity to the Sun". Visuals related to the activities in the Solar System and Eclipses unit are presented in Figure 1 and 2.

Figure 1. Solar System

Figure 2. Planet Sorting

Six activities were carried out for the Systems in Our Body unit. The topics and concepts of this unit related to cartilage, bone and bone types, joint and joint types, muscles and muscle types; the structure and organs that constitute the digestive system, physical and chemical digestion, enzymes, the function of the liver, pancreas, and pancreas in digestion; structures and organs that constitute the circulatory system, structure and function of the heart, blood vessels, systemic circulation and microcirculation, blood types, blood donation, circulatory system; structures and organs that constitute the respiratory system, lungs were instructed using AR applications such as Vucudumuz 4D, Human Anatomy 4D, Luke AR. These activities targeted the following gains "Explains the structures of the musculoskeletal system with examples", "Explains the functions of the structures and organs that constitute the digestive system using models", "Explains the functions of auxiliary organs in digestion", "Explains the functions of the structures and organs that constitute the circulatory system using models", "Examines the systemic circulation and microcirculation on the scheme and explains their functions" and “Explains the functions of the structures and organs that constitute the respiratory system using models”. Visuals related to the activities in the Systems in Our Body unit are presented in Figure 3-4-5-6.

Figure 3. Skeleton System

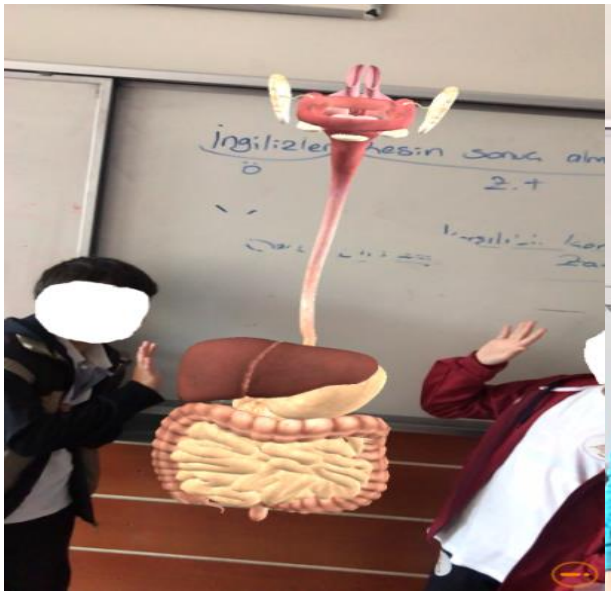

Figure 4. Digestion System

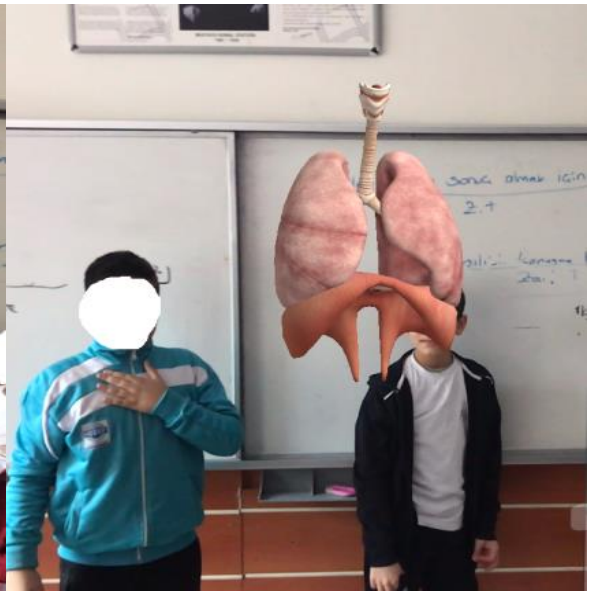

Figure 5. Respiratory System

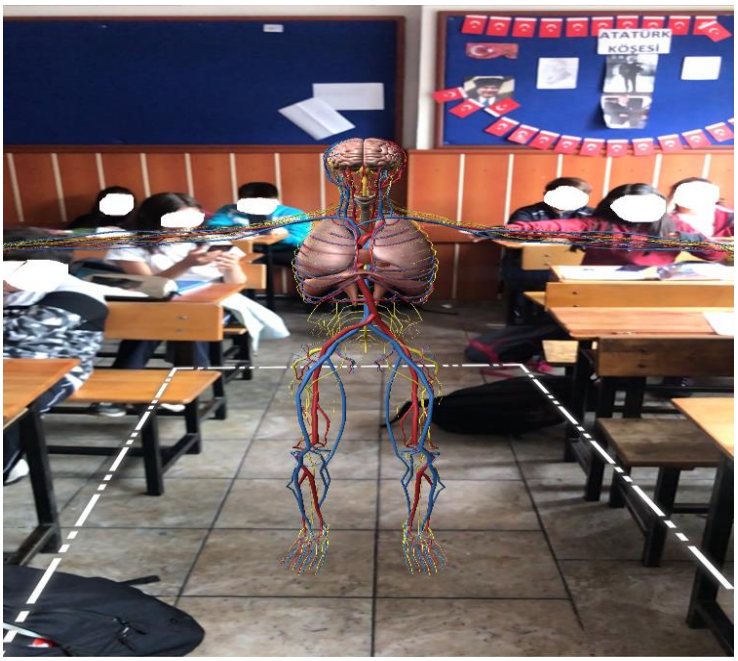

Figure 6. Circulatory System

Teacher-centered traditional teaching method was used in the CG, by sticking to the curriculum and textbook. Teacher-centered traditional teaching is the instruction where the teacher is active and the student is passive in the classroom and activities (Aydede & Matyar, 2009). Following the application process, the posttest and the semi-structured interview form were administered on the EG to determine their opinion on AR technology, whereas only the posttest was administered on the CG. One month after the post-test application, the recall test, which is exactly the same as the post-test, was administered on both experimental and control groups to measure the permanence of the learning.

Data Collection Tools

In order to determine the students' level of recalling, the Solar System and the Systems in Our Body Achievement Test, developed by the researcher, was used. A semi-structured interview form prepared by the researcher was used for collecting students' opinions on AR applications.

The Solar System and the Systems in Our Body achievement test

The Solar System and the Systems in Our Body Achievement Test, developed by the researcher, was used in the study to determine the students' level of recalling the knowledge. The gains included in the achievement test prepared for the "Solar System and Eclipses" and the "Systems in Our Body" units, which are the first and second units of 6th grade Science curriculum, were specified according to 2018 science curriculum (MEB, 2018). Item analysis was performed for the validity of the 45-question test prepared for 9 gains. Malformed items were detected upon the item analysis and difficulty and discrimination level of the items were confirmed (Buyukozturk et al., 2016). A total of 402 students have participated in the pre-pilot application. In item analysis, the focus was on item discrimination and item difficulty. Regarding the reference values of the item discrimination indexes, items with a discrimination index of 0.40 and above are considered to be very good, and items between 0.30-0.39 are quite good. Items with a discrimination index of 0.20-0.29 can be revised and modified, and items with a value of 0.19 or less should be removed from the test (Crocker & Algina, 1986). Regarding item difficulty, the reference value ranges between 1 and 0. As this value approach to 1, the item becomes easier and vice versa (Buyukozturk et al., 2016). Following the analysis, 18 items with a discrimination index of 0.19 and below were removed from the test. The test, whose number of items was reduced to 27, get ready for pilot implementation. Regarding the item analysis of the data obtained from the pilot application conducted with 43 girls and 45 boys, item difficulty and discrimination indices were found to be within the reference values. The reliability coefficient of the developed test was calculated as KR20 (Alpha) 0.85.

Semi-structured interview form

Interview is the preferred method in most of the qualitative studies (King et al., 2019). After the implementation process and the measurement of academic achievements in the study, an eight-question semi-structured interview form developed by the researcher was used to determine the opinions and thoughts of the students in the EG about this experience. The questions were prepared under three themes: thoughts on AR technologies, experiences on AR technology and the contribution of AR technology to learning. The interview form was administered on 26 students in the EG. 40 minutes were given to answer the questions in the form. Two faculty members who are experts in science education and measurement and evaluation were consulted during the preparation of the questions. In addition, opinions of two science teachers, one working in the science, arts and education center affiliated to the Ministry of National Education and the other in a secondary school, were asked. In order to test the comprehensibility of the questions, a preliminary interview was held with 10 students attending 6th grade. The interview form was finalized upon the corrections made according to the given feedback.

Data Analysis

While analyzing the quantitative data, TAP (Test Analysis Program) was used in the preparation of the achievement test, and SPSS 20 software was used to compare the data obtained from the pretest, posttest and recall test. In order to make the raw data obtained during the study usable, numerical values were given to each answer and they were entered into the databases of the programs.

Descriptive analysis was performed on the data collected from the control and experimental groups, and the arithmetic mean, standard deviation, maximum and minimum values, skewness, kurtosis and Shapiro-Wilk values were calculated. Regarding the normality check of the score distribution, Buyukozturk (2005) suggested to use Shapiro-Wilk normality test if the group size is less than 50, and Kolmogrov-Smirnov normality test if the group size is greater than 50. Regarding the p value calculated as a result of these tests, the values smaller than 0.05 are interpreted as the scores deviate significantly from the normal distribution, that is, the normality condition is violated (Buyukozturk, 2005). In this study, Shapiro-Wilk normality test was administered because the sample size was less than 50. Another parameter that indicates normality is skewness and kurtosis. In particular, the skewness is more useful than the kurtosis. Having a skewness of zero (“0”) is an indicator of normal distribution, but it is extremely difficult to collect data with normal distribution in the implementation (Coskun et al., 2015). If the skewness is between +1 and -1, it is assumed that there is no significant deviation from the normal distribution (Buyukozturk, 2005).

Dependent groups t-test was performed to determine whether the difference between the mean scores of the dependent groups in the study was significant or not, whereas independent samples t-test was used to determine the significance of the difference between the mean scores of independent groups (Buyukozturk, 2005). Normal

distribution of data is required in all parametric tests, while in some tests such as t-test, this condition is not required. They can be used safely up to a certain deviation from normal distribution (Coskun et al., 2015). Covariance analysis (ANCOVA) was used to test whether the group means adjusted according to the common variable associated with the dependent variable differ significantly from each other (Buyukozturk, 2015). The covariance analysis, which is a parametric test, gives strong results if the assumptions are met, and variance analysis and regression analysis are used together to calculate the difference between the means of the groups (Kalayci, 2010).

Content analysis was used to analyze the data obtained from semi-structured interview form administered on the students of the EG. The objective of preferring content analysis is to reach the concepts and relationships that explain collected data. The process carried out in this analysis is to group the data within the framework of certain concepts and interpret the themes in a way that the reader can understand (Yildirim & Simsek, 2016). The analysis process was completed in three stages, namely data processing, visualization of the data, and inference and confirmation (Miles & Huberman, 1994). In the first stage, the data were examined. In the second stage, codes and categories were specified and grouped under three themes. The third stage tries to summarize the data in an understandable way. In order to comprehend the data obtained from the semi-structured interview form more clearly, the answers collected from the students were classified under the themes suitable for the objectives of the study. Similar data obtained from the form were grouped under a common theme and students' answers were supported with quotations to ensure the internal validity of the research. Each student was given a code name (P1-P), so that their identity was kept confidential. In order to ensure external validity, all stages of the research have been examined in detail. In order to ensure the reliability of the research, the data were analyzed independently by the researchers and then compared. The two researchers analyzed the data obtained from the interview forms at different times. Also, during the research, researchers often came together and decided on the themes, categories and codes to be used in the study. The analysis of the data obtained from the interview form was done by two independent evaluators. No calculation was made in this process, only a few codes differing among the evaluators were discussed and agreed on. A harmony was observed among the coding of the evaluators.

Findings

This section includes the findings obtained in line with the objectives and sub-objectives of the research. Firstly, the distributions of the data obtained from achievement test administered on control and experimental groups were analyzed. Table 1 shows the student numbers of the groups, the average scores obtained from the achievement test, standard deviations, skewness, kurtosis, mid-range minimum, maximum and Shapiro-Wilk normality test results.

Table 1. Descriptive Statistics of the pretest, posttest and recall test scores from Achievement test

Tests	Groups	N	$\bar{X}$	sd	Skew.	Kurt.	Mid-range	Min	Max	Shapiro-Wilk
Pretest	Exp.	26	10.34	2.79	-.54	.65	12	4	16	.31
	Control	24	10.83	2.20	-.30	-.65	8	6	14	.27
Posttest	Exp.	26	22.69	2.61	-.37	-.34	10	17	27	.50
	Control	24	20.08	2.81	.49	.53	12	15	27	.59
Recall	Exp.	26	22.26	2.47	-.12	-.47	10	17	27	.48
test	Control	24	17.54	3.72	.19	-.15	15	10	25	.88

Regarding Table 1, mean pre-test score of the CG ($\bar{X}$ = 10.83) and EG ($\bar{X}$ = 10.34) were observed to be quite close to each other, and accordingly the achievement level of the groups was concluded to be similar before the application. Regarding skewness, kurtosis and Shapiro-Wilk normality values of the pretest, posttest and recall test, the scores obtained from all tests exhibited normal distribution ($p>.05$)

Comparison of experimental and control group students' pretest and posttest scores

In order to answer, “Is there a significant difference between EG / CG students’ pretest and posttest achievement test scores?” questions, experimental and control groups’ pre-test and post-test scores were tested. Since the scores of both tests were normally distributed, the significance of the difference between the mean scores was tested by “dependent groups t-test”.

Table 2. t-test results of control and experimental groups' pretest and posttest scores

	Test	*N*	$\bar{X}$	*SD*	*sd*	*t*	*p*
Experiment	Posttest	26	22.69	2.61	25	24.43	.000*
	Pretest	26	10.34	2.79			
Control	Posttest	24	20.08	2.81	23	14.19	.000*
	Pretest	24	10.83	2.20			

*p<.05

Regarding table 2, a significant difference was observed between pretest and posttest scores of the EG students (t(25)=24.43, p<.05). The average score of the EG increased from 10.34 to 22.69, which corresponds to an increase of approximately 53%. This finding is higher than CG's achievement increase. A significant difference was also observed between pretest and posttest scores of the CG students (t(23)=14.19, p<.05). The average score of the CG increased from 10.83 to 20.08, which corresponds to an increase of approximately 46%.

Comparison of experimental and control group students' posttest scores

In order to answer, "Is there a significant difference between EG and CG students' average posttest scores adjusted according to pretest scores?" question, the significance of the difference between experimental and control groups' average pretest scores was tested first. Regarding independent samples t-test results, no statistically significant difference was observed between the average pretest scores of the EG and CG students (t = -.68; p>.05). Then, the significance of the difference between experimental and control groups' average posttest scores was tested by independent samples t-test. The result of independent samples t-test is given in Table 3.

Table 3. t-test results of control and experimental groups' posttest scores

Group	$\bar{X}$	SD	sd	t	p	η2
Control	20.08	2.81	48	3.39	.001*	0.193
Experimental	22.69	2.61				

*p<.05

Regarding Table 3, the average posttest score of the EG was observed to be higher than the CG. Accordingly, a statistically significant difference was observed between EG and CG students' posttest scores (t = 3.39; p< .05). When the effect size was calculated, the large effect size (η2 =.193) (Cohen, 1988) demonstrated a significant difference between the groups.

Comparison of experimental and control group students' recall test scores

In order to answer, "Is there a significant difference between EG and CG students' average recall test scores adjusted according to posttest scores?" question, the significance of the difference between experimental and control groups' average posttest scores was tested first. In table 3, a statistically significant difference was observed between EG and CG students' posttest scores (t = 3.39; p<.05). Therefore, covariance analysis (ANCOVA) was performed for experimental and control groups' posttest and recall test scores.

Before performing the covariance analysis, certain assumptions were checked and the covariant was specified. In this sub-problem, the covariant was specified as the scores that the groups received from Posttest. The assumptions of the covariance analysis, namely whether the scores of the groups show normal distribution, whether there is a linear relationship (correlation) between the common variable (covariant) and the dependent variable, and the homogeneity of the regression curves and the group variances were checked. For normality assumption, Skewness, Kurtosis and Shapiro-Wilk normality test results of Table 1 were reviewed, and it was concluded that the scores did not deviate excessively from the normal distribution.

The relationship between the dependent variable and the covariant was examined by Pearson correlation analysis. The results showed that the relationship between the dependent variable (recall test scores) and the covariant (posttest scores) is significant and high for both the EG (r =.87; p <.01) and CG (r =.84; p <.01), therefore a linear relationship was observed between them. In order to check the assumption of homogeneity of regression curves within groups, the difference between the slopes of regression lines was examined by "Group x Posttest" joint effect test. The results of the analysis are given in Table 4.

Table 4. "Group x Posttest" joint effect test outcomes

Dependent Variable	Source	Sum of Squares	sd	Mean of Squares	F	p	η2
Recall Test	Adjusted Model	621.52[a]	3	207.17	73.03	.00	,826
	Constant	.30	1	.30	.10	.74	,002
	Groups	13.52	1	13.52	4.76	.03	,094
	Posttest	331.80	1	331.80	116.97	.00	,718
	Groups *Posttest	7.58	1	7.58	2.67	.10	,055
	Error	130.47	46	2.83			
	Total	20752.00	50				
	Adjusted Total	752.00	49				

Regarding Table 4, it was concluded that the difference between the slopes of the regression lines is not significant, in other words the regression curves are homogeneous (F (1.46) = 2.67, p>.05). When the effect size was calculated, it was estimated that the effect size was η2 =, 055. Accordingly, this value is interpreted as a medium effect size (Cohen, 1988). The results of the Levene test performed to check the equality of variances assumption also showed that the variances of the groups were homogeneous (F = 3,01, p>.05). As a result of these analyzes, all assumptions of ANCOVA are provided, showing that the significance of the difference between the experimental and control groups' average recall test scores adjusted according to the posttest scores can be analyzed by ANCOVA. The results of the covariance analysis are given in Table 5.

Table 5. ANCOVA results of experimental and control groups' recall test scores

Dependent Variable	Source	Sum of Squares	sd	Mean of Squares	F	p	η2
Recall Test	Adjusted Model	613.94[a]	2	306.97	104.50	.00	.81
	Constant	.64	1	.64	.21	.64	.00
	Posttest	335.01	1	335.01	114.05	.00	.70
	Groups	48.13	1	48.13	16.38	.00	.25
	Error	138.06	47	2.93			
	Total	20752.00	50				
	Adjusted Total	752.00	49				

Regarding Table 5, a statistically significant difference was observed between EG and CG students' recall test scores adjusted according to the posttest scores (F(1,47)= 16,38, p<.05). The effect size of the difference was calculated as η2 =.25. Regarding this effect size, we can say that independent variable has a small effect on the dependent variable. In other words, 25.9% of the change in the dependent variable results from the applied method. The results of the Bonferroni comparison test between the adjusted averages of the groups are given in Table 6. Regarding Table 6, a statistically significant difference was observed between experimental and control groups' adjusted recall test scores (p <.05), in favor of the EG.

Table 6. Bonferroni Comparison Test Results of the Groups' Adjusted Recall Test Scores

Group	Difference in Means	Standard Error	p	Source of the Difference
Experimental Control	2.18	.54	.00	Experimental >Control

Opinions of experimental group students on AR **technology**

This part of the study includes the findings obtained from the semi-structured interview form consisting of eight questions in which the opinions of the students in the EG about the AR technology are taken. The interview form was administered on the 26 students of the EG. The answers given to the eight questions in this form were analyzed. For a clearer understanding of the data obtained from the interview form, the answers given by the students were classified under themes suitable for the objective of the study. These analysis results were also supported with quotations from student opinions. Theme, category, code and frequency values created for AR practices are presented in Table 7.

Table 7. Theme, category, code and frequency table for AR applications

Theme	Category	Code	*f*
Thoughts on AR Technologies	Description of AR	3D image	19
		Phone app	5
		Feeling like you're there	1
		Examination	1
	The remarkable features of the applications	Being 3D/4D	16
		Moving images	4
		Visible on the phone	2
		Having a voice narration	2
		Being fun	1
		Effective on the retention of the knowledge	1
		Having card feature	1
	Suggestions for other courses	Social Sciences	17
		Mathematics	8
		English	2
		Turkish	1
		Science	1
		Physical education	1
	Topics suggestions	History	11
		Sets	1
		Our place in the world	1
		Life on earth	1
		Individual and society	1
		Parallel and meridian	1
		Dodgeball	1
Experiences on AR Technologies	Previous use of AR applications	I have not used	18
		I don't remember the name	5
		Uzay 4D	3
		Vucudumuz 4D	2
		Anatomy 4D	1
	Problems experienced	Some	2
		None	24
The Contribution of AR Technology to Learning	The topics and concepts learned	The Solar System	16
		Systems in Our Body	15
		Topics and concepts in Science	3
		The concept of prejudice	1
	Helping them to understand the topic	Yes	24
		No	1
		Somehow	1
	How it helped them to understand the topic	Repetitions	13
		Visuals	7
		Being fun	1
		Audio	1
	Effect on the permanence of what was learned	Effective with the visuals	17
		Effective by being repetitive	3
		Effective by being fun	3
		Not effective	2
		Not fully effective	1

Students' answers regarding AR applications were grouped under three themes: thoughts on AR technologies, experiences on AR technology and the contribution of AR technology to learning (Table 7). There are four categories under the theme of thoughts on AR technologies: description of AR, remarkable features of the applications, suggestions for other courses and topic suggestions. The code mostly mentioned under the description of AR category is 3D image. A student on this subject said, “Seeing an item from all sides, seeing it as 4D or 3D. (P-1)”, whereas another similar opinion was “We can see objects in three dimensions (P-17)”. The other codes mentioned under this category were phone app, feeling like you’re there and examination. The code mostly mentioned under the remarkable features of the applications category is being 3D/4D. A student on this

subject stated her opinion as “Being 3D/4D attracted my attention (P-27)”. Another similar opinion was "Being 3- or 4-dimensional drew my attention (P-19)". The other codes mentioned under this category were the presence of moving images, being visible on the phone, having fun, having a voice narration, being effective in the retention of the knowledge, and having a card feature. The mostly repeated code under the category of suggestions for other courses is social sciences. A student on this subject expressed his opinion as “the first Turkish states in social sciences (P-5)”. Another similar view was "Social Sciences, Anatolia Homeland of the Turks (P-7)". Other codes mentioned under this category were mathematics, English, Turkish, science and physical education. The most frequently mentioned code under the category of topic suggestions is history. A student on this subject expressed her opinion as "I would like to see it in Social Sciences course and on the topic of History (P-14)". Another similar opinion was "Social Sciences History (P-13)". Other codes mentioned under this category were sets, our place in the world, life on earth, individual and society, parallel and meridian, and dodgeball.

There are two categories under the theme of experiences on AR technology: previous AR applications and problems experienced. The code mostly mentioned under previous AR applications category was I have not used. A student said, “I did not use it (P-15)” on this subject. Another similar opinion was, “I have not used such an application before. (P-10)”. The other codes mentioned under this category were, I don't remember the name, uzay 4D, vucudumuz 4D, anatomy 4D. None is the code that was mostly repeated under the category of problems experienced. A student on this subject expressed his opinion as "No, there was not (P-25)". Another similar view was "no problem occurred (P-20)". The other code specified under this category is some problems. A student on this subject expressed her opinion as “yes, my phone's camera has warmed up (P-1)”. Another similar opinion was “There was a problem with the application. It was closing immediately. (P-13)”.

The theme of the contribution of AR technology to learning is presented under four categories: the topics and concepts learned, helping them understand the topic, how it helped them to understand the topic and its effect on the permanence of what was learned. The most frequently mentioned code under the category of topics and concepts learned is The Solar System. A student on this subject expresses her opinion as "I learned a lot about the Solar System (P-3)". Another frequently repeated code is Systems in Our Body. A student stated on this subject that “Yes, I learned the topic of our body better (P-9)”. Other codes mentioned under this category are topics and concepts in Science and prejudice. The code mostly mentioned under the category of helping them understand the topic is yes. A student on this subject said, “Yes, I learned through these applications. It made us understand the topics better. (P-21)”. Another similar view was, “Yes, it helped me to learn. I saw it more closely. (P-12)”. The other codes mentioned under this category are no and somehow. The most mentioned code under the category of how it helped them understand the topic was repetitions. A student on this subject expressed his opinion as "I have repeated the topic and it was reinforced (P-23)". The other codes mentioned under this category are visuals, being fun, audio. The code mostly repeated under the category of effect on the permanence of what was learned is effective with the visuals. A student on this subject expressed his opinion as “yes, because 3D is better at learning (P-22)”. Another similar opinion was “it helped. In particular, when there was something I forgot in the exam, the images in AR came in my mind (P-8)”. The other codes mentioned under this category effective by being repetitive, effective by being to fun, not effective, not fully effective.

Discussion and Conclusion

This study aims to investigate the effect of AR applications in science education on the level of recalling the learned knowledge of 6^{th} grade students. For this purpose, the data obtained from “The Solar System and Systems in Our Body Achievement test” developed by the researcher and the semi-structured interview form were analyzed and the effect of AR applications on the academic achievement of 6^{th} grade students and their level of recalling the learned knowledge in science course was determined. More consistent results were obtained by supporting these quantitative analyzes with the qualitative findings obtained from the semi-structured interview form.

Regarding the findings obtained by comparing pretest and posttest scores of experiment and CG students, a significant difference was observed between them. The increase rate of the EG is higher than that of the CG, which shows us that the application in the EG was more effective than the application in the CG. Regarding the findings obtained from the comparison of experiment and CG students’ posttest scores, a statistically significant difference was observed between them ($t = 3.397$; $p > .05$). This finding shows that the science lesson instructed using AR applications has a positive effect on students' academic achievement compared to the science lesson instructed only by sticking to the textbook. These results of the research are similar to the results of other studies in the literature (Abdusselam & Karal, 2012; Ates, 2018; Chiang, Yang, & Hwang, 2014; Demirel, 2017;

Demirel, 2019; Eroglu, 2018; Fidan, 2018; Fleck & Simon, 2013; Gungordu, 2018; Kul, 2019; Ozarslan, 2013; Shelton & Hedley, 2002; Sirakaya, 2015; Sin & Badioze-Zaman, 2010; Sahin 2017; Senturk, 2018; Yildirim, 2018). However, there are some studies in the literature showing that AR applications did not have a positive effect on academic achievement. Erbas (2016) reported that the use of AR did not create a positive difference on the academic achievement of students in the practice carried out within the scope of biology lesson. Gun & Atasoy (2017) reported that their AR applications performed within the scope of mathematics lesson did not make a positive difference in students' academic achievements. Yen et al. (2013) reported that no positive difference occurred on students' academic achievement as a result of using AR applications on university students' in the phases of the moon topic. The results of these studies do not overlap with the results of this study.

The findings obtained by comparing EG and CG students' recall test scores showed that science lesson instructed with AR applications had a positive effect on students' level of recalling the learned knowledge compared to the lesson instructed by sticking to the textbook only. The literature review revealed that there are few studies measuring the level of recalling the knowledge learned through AR applications. Fidan (2018) reported that AR applications applied with problem-based activities within the scope of force and energy unit had a positive effect on students' level of recalling the knowledge. In the study examining the effect of AR applications on academic achievement within the scope of the "particle structure of matter and pure substances" topic of 7^{th} grade science course, Ates (2018) reported that instruction supported by AR applications positively affected the permanence of the knowledge. The following features of AR technology may have been effective in achieving these results; AR is a new technology, thus it may have attracted the attention and interests of the students who faced with this technology for the first time, which affected their motivation and increased their achievement. Similar results are seen in the literature (Delello, 2014; Di Serio, Ibáñez, & Kloos, 2013; Gun, 2014; Korucu et al., 2016; Kucuk, 2015; Sahin, 2017; Senturk, 2018; Sirakaya, 2015; Tomi & Rambli, 2013; Yen et al., 2013). The realistic image quality of AR applications may have been effective in attracting students' attention. Students can perceive three-dimensional objects appearing on AR application cards as magic (Billinghurst et al., 2001). In this way, a fun learning can be realized (Erbas, 2016; Senturk, 2018). Students do not have the chance to make observation on every subject of The Solar System and Systems in Our Body units, and AR applications allowed them to make observation with their realistic images, thus it is expected to attract students' attention. Textbooks are also insufficient in this sense. The literature also contains studies reporting that AR applications concretize abstract concepts that cannot be observed via 3-D visuals and present complex topics in a comprehensible way (Cetin, 2019; Gun, 2014; Gungordu, 2018; Klopfer & Squire, 2008; Senturk, 2018; Shelton & Hedley 2002; Wu, Lee et al., 2013).

The opinions of the students in the EG on AR technology were taken and they were grouped under three themes: thoughts on AR technologies, experiences on AR technology, and the contribution of AR technology to learning. The results reached under the theme of thoughts on AR technologies have shown that students have reached the level of describing AR technology even though they have not used any AR applications before. Another result has shown that three-dimensional visuals in AR applications attracted students' attention. There are studies in the literature achieving similar results (Cetin, 2019; Erbas, 2016; Fidan, 2018; Gungordu, 2018). Another result showed that students want to use AR applications in different courses and topics. There are studies in the literature achieving similar results (Ates, 2018; Cetin, 2019; Demirel, 2019; Erbas, 2016; Fidan, 2018; Gun, 2014; Gungordu, 2018; Kul, 2019; Ozarslan, 2013; Sirakaya, 2015). The results obtained under the theme of experiences on AR technology showed that students have not used AR application before, and they met AR applications with this study. Even though the students were using AR applications for the first time, the growth of the new generation intertwined with technology provided an advantage in terms of harmony. There are studies in the literature achieving similar results (Erbas, 2016; Kucuk, 2015; Senturk, 2018; Yildirim, 2018). Another outcome showed that the students had no problems in using the applications during the research. There are studies in the literature showing similar results (Gun, 2014; Gungordu, 2018; Kul, 2019; Ozarslan, 2013). Although no problems occurred in this study, there are several studies in the literature, reporting problems in using AR applications. Cetin (2019) reported that students were distracted because of some technical problems in the hardware and software. Senturk (2018) reported that problems arising from external factors such as light, output and image quality can be experienced. Gun (2014) reported difficulties related to lighting and image blur due to camera. The resulting difference may be due to the use of different and diverse applications in this study. The results achieved under the theme of the contribution of AR technology to learning showed that AR applications played an active role in sustaining students' academic achievement and the learned knowledge, that is, improving the recall levels, and this is mainly due to the 3D visuals used by the applications. There are studies in the literature indicating similar results (Ates, 2018; Cetin 2019; Fidan, 2018; Gun, 2014; Gungordu, 2018; Shelton & Hedley, 2002; Sahin, 2017; Senturk, 2018; Sirakaya, 2015; Tomi & Rambli, 2013; Yildirim, 2018).

As a result, the academic achievement of the EG, in which AR applications were actively used by the students in the science course, was found to be higher than the academic success of the CG, where the course was instructed only by sticking to the book. The analysis of the mean scores of the recall tests administered to measure how much the experiment and CG recall the knowledge they learned, in other words the permanence of their knowledge, EG students were found to be statistically significantly more successful. More generally, the use of AR applications in science class has a positive effect on 6th grade students' level of recalling the learned knowledge. The review of the studies in the literature showed that they are in line with the results this study (Ates, 2018; Barmaki et al., 2019; Fidan 2018; Huang et al., 2019; Lu et al., 2014; Pérez-López & Contero, 2013).

Recommendations

In line with the results obtained from this study, the following suggestions were developed: It is recommended to use AR applications actively and regularly in science lessons. Similar studies can be conducted with different samples, at different grade levels. This study involved The Solar System and The Systems in Our Body units in science curriculum. The effect of AR technology on different topics can be examined by focusing on different units, especially on teaching abstract concepts. Both this study and similar studies focused on the effect of AR applications on academic achievement, attitude and motivation. Further studies analyzing the effect of AR technology on different skills and variables such as 21st century skills, life skills, and thinking skills, may be conducted. Very few problems occurred with the AR applications used in this study. The AR applications used have attracted students' attention with their image quality and entertaining content and motivated them towards the course. While conducting similar studies, more attention may be paid to the selection of applications; applications that are more entertaining in terms of content, materials and software, and that can run in all operating systems can be preferred. In addition, these applications were carried out through the phone. The researchers were advised to be procured in terms of phones or tablets in order to avoid problems during the applications.

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

References

Abdusselam, M. S. (2014). Teachers' and students' views on using augmented reality environments in physics education: 11th grade magnetism topic example. *Pegem Journal of Education and Instruction, 4*(1), 59-74.

Abdusselam, M. S., & Karal, H. (2012). Fizik öğretiminde artırılmış gerçeklik ortamlarının öğrenci akademik başarısı üzerine etkisi: 11. Sınıf manyetizma konusu örneği [The effect of mixed reality environments on the students' academic achievement in physics education: 11th grade magnetism topic example]. *Journal of Research in Education and Teaching, 1*(4), 170-181.

Akpinar, E., Aktamis, H., & Ergin, O., (2005). Fen bilgisi dersinde eğitim teknolojisi kullanılmasına ilişkin öğrenci görüşleri [Student's views on the use of educational technology in science course]. *The Turkish Online Journal of Educational Technology, 4*(1), 93-100.

Aktamis, H., & Arici, V. A. (2013). Sanal gerçeklik programlarının astronomi konularının öğretiminde kullanılmasının akademik başarı ve kalıcılığa etkisi [The effects of using virtual reality software in teaching astronomy subjects on academic achievement and retention]. *Mersin University Journal of the Faculty of Education, 9*(2), 58-70.

Arici, V. A. (2013). *Fen eğitiminde sanal gerçeklik programları üzerine bir çalışma:" Güneş sistemi ve ötesi: Uzay bilmecesi" ünitesi örneği [A study on 3D-vırtual realıty ın scıence educatıon programs: Solar system and beyond: space puzzle" unıt sample]* (Unpublished master's thesis). Adnan Menderes University, Aydın.

Ates, A. (2018). *7. sınıf fen ve teknoloji dersi 'maddenin tanecikli yapısı ve saf maddeler' konusunda artırılmış gerçeklik teknolojileri kullanılarak oluşturulan öğrenme materyalinin akademik başarıya etkisi [7 th grade scıence and technology course "structure of the substance and pure substances" on augmented realıty created usıng technology learnıng materıal effect on academıc achıevement]* (Unpublished master's thesis). Niğde Ömer Halisdemir University, Niğde.

Aydede, M. N., & Matyar, F. (2009). The effect of active learning approach in science teaching on cognitive level of student achievement. *Journal of Turkish Science Education, 6*(1), 115-127.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355- 385.

Barmaki, R., Yu, K., Pearlman, R., Shingles, R., Bork, F., Osgood, G. M., & Navab, N. (2019). Enhancement of anatomical education using augmented reality: An empirical study of body painting. *Anatomical sciences education, 12*(6), 599-609.

Billinghurst, M., Kato, H., & Poupyrev, I. (2001). The magic book-moving seamlessly between reality and virtuality. *IEEE Computer Graphics and Application, 21*(3), 6-8.

Buyukozturk, S. (2005). *Sosyal bilimler için veri analizi el kitabı [Manual of data analysis for social sciences] (5th ed.)*. Ankara: Pegem Yayıncılık.

Buyukozturk, S. (2015). *Sosyal bilimler için veri analizi el kitabı: İstatistik, araştırma deseni [Data analysis handbook for social sciences: Statistics, research design]*. Ankara: Pegem Yayıncılık.

Buyukozturk, S., Kılıç-Çakmak, E., Akgün, Ö., Karadeniz, Ş., & Demirel, F. (2009*). Bilimsel araştırma yöntemleri [Scientific research methods. (3rd ed.)* Ankara: Pegem Yayıncılık

Buyukozturk, Ş., Bokeoglu, O., & Koklu, N. (2016). *Sosyal bilimler için istatistik [Statistics for social sciences*]. Ankara: Pegem Yayıncılık.

Cakir, R. & Yildirim, S. (2009). What Do Computer Teachers Think About the Factors Affecting Technology Integration in Schools? *Elementary Education Online, 8*(3), 952-964.

Cetin, S. (2019). *Artırılmış gerçeklik uygulamalarının teknik resim dersinde ortaöğretim öğrencilerinin akademik başarıları, tutumları ve uzamsal görselleştirme becerilerine etkisi [The effect of augmented reality applications on academic achievement, attitudes and spatial visualization skills of vocational school students in technıcal drawing course]* (Unpublished master's thesis). Uludağ University, Bursa.

Chiang, T., Yang, S., & Hwang, G.J. (2014). An augmented reality-based mobile learning system to improve students' learning achievements and motivations in natural science inquiry activities. *Educational Technology & Society, 17*(4), 352-365.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Hills-dale, NJ: Lawrence Earlbaum Associates

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education (6th ed.)*. London: Routledge Falmer.

Coskun, R., Altunisik, R., Bayraktaroglu, S. & Yildirim, E. (2015). *Sosyal bilimlerde araştırma yöntemleri SPSS uygulamalı (8. Baskı).* Sakarya: Sakarya Kitabevi

Crocker, L., & Algina, J., (1986). *Introduction to classical and modern test theory.* Ohio: Cengage Learning.

Delello, J. A. (2014). Insights from pre-service teachers using science-based augmented reality. *Journal of Computers in Education, 1*(4), 295–311.

Demirel, G. (2019). *Artırılmış gerçeklik uygulamaları ile işlenen fen bilimleri dersinin 7. Sınıf öğrencilerinin akademik başarılarına ve artırılmış gerçeklik uygulamalarına karşı tutumlarına etkisi [The effect of a science lecture taught using augmented reality applications on 7th grade students' academic achievement and attitudes toward augmented reality applications]* (Unpublished master's thesis). Gazi University, Ankara

Demirel, T. (2017) *Argümantasyon yöntemi destekli artırılmış gerçeklik uygulamalarının akademik başarı, eleştirel düşünme becerisi, fen ve teknoloji dersine yönelik güdülenme ve argümantasyon becerisi üzerindeki etkisinin incelenmesi [The effect of augmented reality activities supported by argumentation approach on academic achievement, critical thinking skills, motivation towards science and technology course and argumentation skills]* (Unpublished doctoral dissertation). Çukurova University, Adana.

Di Serio, A., Ibáñez, M. B., & Kloos, C. D. (2012). Impact of an augmented reality system on students motivation for a visual art course. *Computers Education, 1*(11), 586-596.

Dror, I. E. (2008). Technology enhanced learning: The good, the bad, and the ugly. *Pragmatics & Cognition, 16*, 215-223. http://dx.doi.org/10.1075/p&c.16.2.02dro

Erbas, C. (2016). *Mobil artırılmış gerçeklik uygulamalarının öğrencilerin akademik başarı ve motivasyonuna etkisi [The effects of mobile augmented reality applications on students' academic achievement and motivation]* (Unpublished master's thesis). Süleyman Demirel University, Isparta.

Eroglu, B. (2018). *Ortaokul öğrencilerine astronomi kavramlarının artırılmış gerçeklik uygulamaları ile öğretiminin değerlendirilmesi [Evaluation of teaching astronomy concept with augmented reality application for secondary student]* (Unpublished master's thesis). Karadeniz Technical University, Trabzon.

Fidan, M. (2018). *Artırılmış gerçeklikle desteklenmiş probleme dayalı fen öğretiminin akademik başarı, kalıcılık, tutum ve öz-yeterlik inancına etkisi [The impact of problem-based science teaching assisted with augmented reality applications on academic achievement, retention, attitude and belief of self-efficacy]* (Unpublished doctoral dissertation). Abant İzzet Baysal University, Bolu.

Fleck, S., & Simon, G. (2013, Kasım). An augmented reality environment for astronomy learning in elementary grades: an exploratory study. *In Proceedings of the 25th Conference on l'Interaction Homme-Machine,* (pp. 14-22), Bordeaux, France

Fraenkel, J. R., Wallen, N. E., & Hyun H. H. (2012). *How to design and evaluate research in education (Eighth Edition).* Boston: McGraw-Hill.

Gun, E. (2014). *Artırılmış gerçeklik uygulamalarının öğrencilerin uzamsal yeteneklerine etkisi [Effects of augmented reality applications on students' spatial abilities]* (Unpublished master's thesis). Gazi University, Ankara.

Gun, E. T., & Atasoy, B. (2017). The effects of augmented reality on elementary school students' spatial ability and academic achievement. *Egitim ve Bilim, 42*(191), 31-51.

Gungordu, D. (2018*). Artırılmış gerçeklik uygulamalarının ortaokul öğrencilerinin atom modelleri konusuna yönelik başarı ve tutumlarına etkisi [The effect of augmented reality applications on secondary school students' achievement of atom models and their attitudes]* (Unpublished master's thesis). Kilis 7 Aralık University, Kilis.

Huang, K. T., Ball, C., Francis, J., Ratan, R., Boumis, J., & Fordham, J. (2019). Augmented versus virtual reality in education: An exploratory study examining science knowledge retention when using augmented reality/virtual reality Mobile applications. *Cyberpsychology, Behavior, and Social Networking*, *22*(2), 105-110.

Kalayci, S. (2010). *SPSS uygulamalı çok değişkenli istatistik teknikleri [SPSS applied multivariate statistics techniques]*. Ankara: Asil Yayın Dağıtım.

Karasar, S. (2004). New communication technologies in education-internet and virtual higher education. *The Turkish Online Journal of Educational Technology–TOJET, 3*(4), 117-125

King, N., Horrocks, C., & Brooks, J. (2019) *Interviews in qualitative research (2nd Ed.).* London: SAGE

Klopfer, E., & Squire, K. (2008). Environmental detectives: The development of an augmented reality platform for environmental simulations. *Educational Technology Research and Development*, *56*(2), 203-228.

Korucu, A. T., Usta, E. & Yavuzarslan, İ. F. (2016). Using Augmented Reality in Education: A Content Analysis of the Studies in 2007-2016 Period. *Journal of Subject Teaching Research, 2*(2), 84-95.

Kucuk, S. (2015). *Mobil artırılmış gerçeklikle anatomi öğreniminin tıp öğrencilerinin akademik başarıları ile bilişsel yüklerine etkisi ve öğrencilerin uygulamaya yönelik görüşleri [Effects of learning anatomy via mobile augmented reality on medical students' academic achievement, cognitive load, and views toward implementation]* (Unpublished doctoral dissertation). Atatürk University, Erzurum.

Kucuk, S., Yilmaz, R. M., & Goktas, Y., (2014). Augmented reality for learning English: Achievement, attitude and cognitive load levels of students. *Education & Science, 39*(176), 393-404.

Kul, H. H. (2019). *Fen eğitiminde artırılmış gerçeklik uygulamaları [Augmented reality applications in science education]* (Unpublished master's thesis). Eskişehir Osmangazi University, Eskişehir.

Lu, W., Nguyen, L. C., Chuah, T. L., & Do, E. Y. L. (2014, September). Effects of mobile AR-enabled interactions on retention and transfer for learning in art museum contexts. *In 2014 IEEE International Symposium on Mixed and Augmented Reality-Media, Art, Social Science, Humanities and Design (ISMAR-MASH'D)* (pp. 3-11). IEEE.

Miles, M. B., & Huberman, M. A. (1994). *An expanded sourcebook qualitative data analysis.* London: Sage.

Ministry of National Education MEB. (2018). *Science course curriculum (primary and middle school 3, 4, 5, 6, 7, 8. classes).* Ankara Ministry of National Education Directorate General for Basic Education.

Ozarslan, Y. (2013). *Genişletilmiş gerçeklik ile zenginleştirilmiş öğrenme materyallerinin öğrenen başarısı ve memnuniyeti üzerindeki etkisi [The effect of augmented reality enhanced learning materials on learners' achievement and learners' satisfaction]* (Unpublished doctoral dissertation). Anadolu University, Eskisehir.

Pamuk, S., Cakir, R., Ergun, M., Yilmaz, H. B., & Ayas, C. (2013). The use of tablet PC and interactive board from the perspectives of teachers and students: Evaluation of the FATİH project. *Educational Sciences: Theory & Practice, 13*(3), 1799-1822.

Parker, J., & Heywood, D. (1998). The earth and beyond: Developing primary teachers' understanding of basic astronomical events. *International Journal of Science Education, 20*(5), 503-520.

Partnership for 21st Century Skills [P21]. (2013). Framework for 21st century learning. Retrieved from http://www.p21.org/about-us/p21-framework

Pérez-López, D., & Contero, M. (2013). Delivering educational multimedia contents through an augmented reality application: A case study on its impact on knowledge acquisition and retention. *Turkish Online Journal of Educational Technology-TOJET, 12*(4), 19-28.

Sahin, D. (2017). *Artırılmış gerçeklik teknolojisi ile yapılan fen öğretiminin ortaokul öğrencilerinin başarılarına ve derse karşı tutumlarına etkisi [Effect of science teaching with the augmented reality technology on secondary school students' achievement and their attitude towards the course]* (Unpublished master's thesis). Atatürk University, Erzurum.

Senturk, M. (2018). *Mobil artırılmış gerçeklik uygulamalarının yedinci sınıf "güneş sistemi ve ötesi" ünitesinde kullanılmasının öğrencilerin akademik başarı, motivasyon, fene ve teknolojiye yönelik tutumlarına etkisinin Solomon dört gruplu modelle incelenmesi [The investigation with solomon four-group design on the effect of using mobile augmented reality(ar) applications in the unit titled "solar system and beyond" in the seventh-grade on the students' academic success, motivation, science and technology attitude]* (Unpublished master's thesis). Kocaeli University, Kocaeli.

Shelton, B. E., & Hedley, N. R. (2002, September). Using augmented reality for teaching earth-sun relationships to undergraduate geography students *In The First IEEE International Workshop Agumented Reality Toolkit*, (pp. 8-pp). IEEE, Darmstadt, Germany.

Sin, A. K., & Badioze-Zaman, H. (2010, June). Live solar system (LSS): Evaluation of an augmented reality book-based educational tool. *In 2010 International Symposium on Information Technology* (Vol. 1, pp. 1-6). IEEE, Kuala Lumpur, Malaysia.

Sirakaya, M. (2015). *Artırılmış gerçeklik uygulamalarının öğrencilerin akademik başarıları, kavram yanılgıları ve derse katılımlarına etkisi [Effects of augmented reality applications on students' achievement, misconceptions and course engagement]* (Unpublished doctoral dissertation). Gazi University, Ankara.

Somyurek, S. (2014). Gaining the attention of generation Z in learning process: Augmented reality. *Educational Technology Theory and Practice, 4*(1), 63-80.

Tomi, A. Bin., & Rambli, D. R. A. (2013). An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow. *Procedia Computer Science, 25*, 123–130.

Wu, H. K., Lee, S. W. Y., Chang, H. Y., & Liang, J. C. (2013). Current status, opportunities and challenges of augmented reality in education. *Computers Education, 62*, 41–49.

Yen, J. C., Tsai, C. H., & Wu, M. (2013). Augmented reality in the higher education: Students' science concept learning and academic achievement in astronomy. *Procedia-social and behavioral sciences, 103*(26), 165-173.

Yildirim, A. & Simsek, H. (2016). *Sosyal bilimlerde nitel araştırma yöntemleri [Qualitative research methods in the social sciences]*. Ankara: Seçkin Yayıncılık.

Yildirim, P. (2018). *Mobil artırılmış gerçeklik teknolojisi ile yapılan fen öğretiminin ortaokul öğrencilerinin fen ve teknolojiye yönelik tutumlarına ve akademik başarılarına etkisi [The impact of science teaching made with mobile augmented reality technology on science and technology attitudes and academic achievement of secondary school students]* (Unpublished master's thesis). Fırat University, Elazığ.

Yilmaz, M. R. (2014). *Artırılmış gerçeklik teknolojisiyle 3 boyutlu hikâye canlandırmanın hikâye kurgulama becerisine ve yaratıcılığa etkisi [Effects of three dimensional storytelling developed with augmented reality technology on narrative skill and creativity]* (Unpublished doctoral dissertation). Atatürk University, Erzurum.

Author Information

Ismet Yildirim
Sehit Gungoren Bostan Middle School
Ministry of National Education
Eskisehir/ TURKEY
Contact e-mail: *yldrm@hotmail.co.uk*
ORCID iD: https://orcid.org/0000-0001-8919-9586

Munise Seckin Kapucu
Eskisehir Osmangazi University
Faculty of Education, Eskisehir/ TURKEY
ORCID iD: https://orcid.org/0000-0002-9202-2703