JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

THE EFFECT OF THE USE OF AUGMENTED REALITY APPLICATIONS ON THE ACADEMIC SUCCESS AND MOTIVATION OF 7TH GRADE STUDENTS

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Abstract. *The aim of this research was to examine the effects of the Augmented Reality (AR)-supported teaching activities on the academic success, motivation of students towards science learning and attitudes of students towards AR application, in the scope of the seventh grade science course, "Solar System and Beyond" unit. For this purpose, "Solomon Four Group Model", which controls the internal and external validity, was used. Research was conducted with 120 students in two different schools and involved two experimental and two control groups established by random method. Experimental (1) and Control (1) groups received data collection tools as pre-test and post-test, while Experimental (2) and Control (2) groups received only post-test. During the six-week research, the students were taught in the experimental groups using the 'Star-Tracker, Spacecraft, iSolarsystem, Space-4D' mobile AR applications, while the control groups were taught with the activities envisaged in the curriculum. "Solar System and Beyond Success Test" and the "Students' Motivation to Science Learning" scale, were used as data collection tools. Findings from the research showed that teaching with AR applications significantly alters the success of students and motivation towards science learning. This showed that teaching with AR applications is effective.*

Keywords: *augmented reality, academic success, solar system, Solomon four-group model, 7th grade students.*

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Introduction

The rapid development of technology enables digital tools and applications to become an ordinary part of our social as well as learning experiences by allowing them to integrate more and more into daily lives. Augmented Reality (AR), which arises from these technological developments, is a technology in which real and virtual objects are allowed to interact simultaneously and virtual-world objects are superimposed on real images (Azuma, 1997). In other words, through these applications, an object that is not actually there is perceived as being there through the display of mobile devices. With these developments in mobile devices, the AR technology is used in many sectors such as health, marketing, education, cinema, advertising and design.

In engineering and architecture education, it is very important to use AR applications since students need to animate objects in their minds in three dimensions. Quintero, Salinas, González-Mendívil and Ramírez (2015) designed an innovative and educational AR application aimed at strengthening mathematical cognitive skills for engineering students. With this application, it was determined that mathematical objects were learned more effectively than teacher drawings or verbal descriptions and students did not have difficulties to imagine in three dimensions.

In the teaching of mathematics, the usage of AR in the classroom is quite important since teaching materials such as papers, pencils, ruler are not sufficient to visualize geometric shapes three dimensionally in the minds of students. In a master thesis study, Gün (2014) carried out a semi-experimental study with 188 sixth grade students with the aim of investigating the effect of supplementing the mathematics course with AR applications named BuildAR on the students' spatial visualization abilities and academic success. Three-dimensional shapes of rigid bodies were created with BuildAR during application. As a result of the study, the students found the AR applications fun and remarkable.

Technology enhanced teaching equipment aids students in visualizing physical concepts and understanding the real world situations and problems. Özarslan (2013) conducted a semi-experimental study with 63 third-grade

https://doi.org/10.33225/jbse/19.18.362

computer science students in order to determine the effect of using AR-enriched learning material on the success and satisfaction levels of students. A functionally enriched application called OptikAR was developed. Eventually, it was determined that the application positively affected student success and satisfaction levels.

In biology education, the usage of interactive AR applications in the teaching of many topics such as the digestive system, circulatory system, plant diversity, insect diversity and classification, ecosystem, protein synthesis resulted in more permanent and effective learning experiences. Yusoff, Zaman and Ahmad (2011) have worked with 63 undergraduate students to determine their perception and acceptance of the AR technology. In the process, the structure of the skin has been observed in three dimensions. As a result of the study, they concluded that students would like to use this technology in the future. According to the result of another research, the students have agreed that the AR platform was a new and useful tool that could be successfully applied for learning purposes in the educational process (Lamanauskas & Bilbokaitė, 2009).

It is also possible to observe the atoms and molecules in three dimensions via AR technology. Nunez, Quiros, Nunez, Carda and Camahort (2008) has carried out a study with 15 college students on inorganic chemistry using AR applications. As a result of the study, it was seen that the three-dimensional crystal structures developed the students' spatial abilities and became an effective support tool that increased their success.

Significance and Aim of Research

It has become easier to bring AR applications into the class and laboratory as teaching tools using mobile devices. In this way, mobile AR applications can be used as an educational tool for teaching of space and universe learning as well as all other science fields. Observing the solar system and the planets clearly cannot be possible in traditional classroom environment. For this reason, AR applications are seen as effective tools in providing access to and visualization of the concepts in astronomy which are difficult to learn. Thus, the unknown features and inaccessible locations of the universe are discovered by the students. They are provided with an opportunity to experience and learn the universe in a realistic and better way. Şahin (2017) has designed supporting material and developed AR activities for the "Solar System and Beyond" unit by consulting with educational design experts with the aim of investigating the effects of supplementing science instruction with AR-enhanced teaching materials on the success levels and attitudes of secondary school students. As a result of this semi-experimental study, it was seen that there was a significant difference in the success levels and attitudes towards the course between the students who took the course in a learning environment supported by AR technology and the success levels of students who were taught in the traditional way. It was also determined that the AR application had a positive influence on the attitudes of the students. In order to investigate the effect of the use of AR applications in the Solar System and Beyond unit on the academic success of students, Kırıkkaya and Şentürk (2018) conducted a quasi-experimental and pre-test & post-test controlled group study with 45 seventh grade students. As a result of the study, it was determined that the AR applications applied in the experimental group increased the academic success.

Since the idea that AR can be used in educational environments has recently become widespread, many applications have been designed to be used in science education. These include Spacecraft-3D, Star Tracker, Star Chart, and Spacecraft -4D, Elements 4D, Dinosaur, Quiver-3D, Octaland-3D, Animal-4D, Augmenter, ARMolVis, Rapp Chemistry, Animal Cell, Space Adventure, iSolarsystem and Solarsystem-AR applications.

It is known that the students of primary school age learn more easily about the objects they are able to see and touch. It is especially important to be able to visualize objects such as the solar system, planets, telescopes and spacecraft in order to comprehend the concepts in "Space and Universe" learning domain. AR technology is a good alternative in terms of three-dimensional visualization of these concepts. The fact that the AR technology provides interactive and reality-enhancing environments suggests that such practices can be used in teaching subjects related to the world and the universe. Considering the fact that the usage of this technology is yet in early stages and not yet widely used in classroom activities and the limited number of reports assessing its use in science education in our country, it has been considered as worthwhile research topic. Given the limited number of studies in which the Solomon four-group model was used, this research also filled a gap in the subject and the AR technology as well as the method employed. In addition, while the researches for AR applications have only just begun, the realization of a fully experimental work based on the Solomon four-group model which protects both internal and external validity reveals the originality of the research. Through this perspective, it is aimed to research the effect of teaching with AR-enhanced on the academic success and motivation of students in the context of "Solar System and Beyond" unit in the Science course. In this respect, the research questions were as follows:

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

1. Is there a significant difference between students in the experimental and control groups in terms of academic success and motivation upon application of the experimental procedure and pre-test stimulation?
2. Does the experimental procedure lead to a significant difference between academic success and motivation pre-test and post-test scores of the groups stimulated by the pre-test in the science course?
3. When pre-test is controlled, does the experimental procedure make a significant difference between the academic success and motivation post-test scores of the students in the pre-test groups?

Research Methodology

Research Design

The use of experimental designs is recommended for strengthening scientific validity in educational research. Experimental design is a research area where data are generated to explore the cause-and-effect relations between variables under the control of researcher (Karasar, 2006). It is very important to ensure internal and external validity in this research area. By ensuring internal validity, it is determined whether the independent variable causes the change in the dependent variable, whereas ensuring external validity allows the researcher to generalize the results of the study to individuals in the population. This research conducted by using "Solomon Four-Groups Design" which is one of the most powerful models that ensures internal and external validity at the same time (Fraenkel & Wallen, 2009). This way, this research enabled the checking of the presence of pre-test sensitivity and thereby added a higher external validity in addition to internal validity. In this context, a symbolic representation of the Solomon four-group model was shown in Table 1.

As shown in Table 1, research groups included two experimental and two control groups. Pre-test scales were applied to one of the groups whereas no pre-test was applied to the other experimental and control groups. In other words, in addition to the effect of the independent variable on the result through the pre-test and post-test applied to the first experimental and control groups, it was determined whether the pre-test has any effect on the results by not applying the pre-test to the second experimental and control group (Rosnow & Rosenthal, 2002).

Table 1. A symbolic representation of the Solomon four-group model.

Groups	Impartiality	Pre-Test	Treatment	Post-Test
Experimental (1)	R	O_1	X	O_2
Control (1)	R	O_3		O_4
Experimental (2)	R		X	O_5
Control (2)	R			O_6

O_1:Experimental (1) pre-test; O_2:Experimental (1) post-test; O_3:Control (1) pre-test; O_4:Control (1) post-test; O_5:Experimental (2) post-test; O_6:Control (2) post-test; X:Experimental intervention, R:Neutrality in the formation of groups

In experimental designs, multiple groups were used; usually experimental and control groups, and these groups should be generated via unbiased assignment (Creswell, 2003). For this reason, research groups were formed through random assignment in this research, so that any changes that could be observed in terms of results between the experimental and control groups are unbiased. These steps were performed according to the Solomon four-group model given in Figure 1.

As shown in Figure 1, experimental groups were educated with the help of AR applications appropriate for the daily plans prepared by researchers, whereas control groups were instructed simply according to the daily plans. "Solar System and Beyond Success Test" and " Students' Motivation to Science Learning " scales were applied as pre-test to the Experimental (1) and Control (1) groups prior to start of the study and as post-test to all groups at the end of the research.

https://doi.org/10.33225/jbse/19.18.362

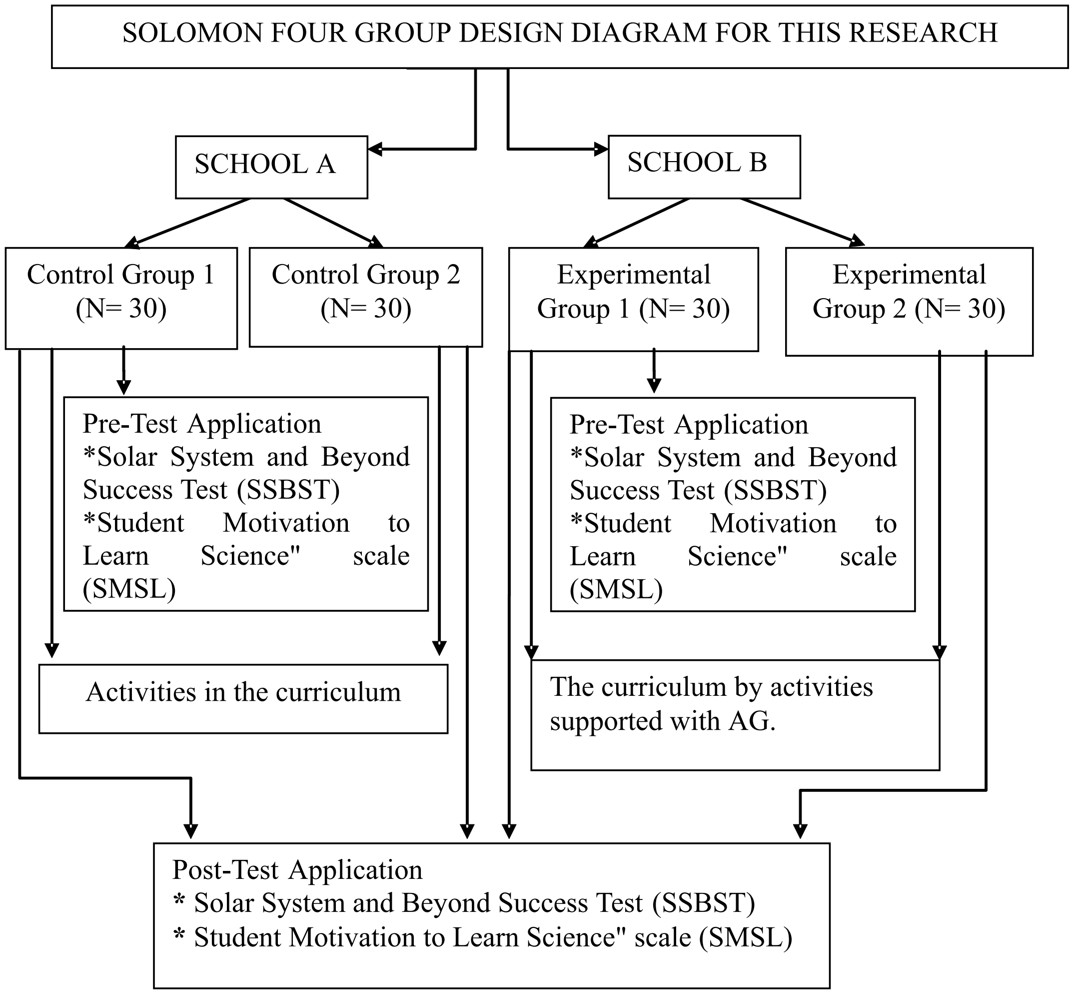

Figure 1. The experimental design.

Research Groups

Before the experimental process, the groups to be included in the research were selected in two state schools in the district of Dilovası, Kocaeli province in Turkey in the second semester of 2016-2017 education years. In the selection attending groups, one-way analysis of variance (ANOVA) was done to determine whether there was a significant difference between the year-end averages of science lecture of all seventh grades in these two schools (Table 2).

Table 2. Results of One-way ANOVA for the science lecture report card averages of the seventh- grade students in school A and B during the academic year of 2016.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*
Between Groups	3237.27	8	404.66	1.53	.15*
Within Groups	72452.61	274	264.43		
Total	79073.66	282			

**p>.05*

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

As seen in Table 2, there was no significant difference between the average grade of Science lectures in the 2016 academic year of all seventh grade groups in two schools ($F_{(1, 282)}$=1.53; p>.05). Since there was no statistically significant difference between the groups, four randomly selected groups were included in the research. Experimental and Control groups were assigned unbiasedly from these four groups. As a result, research was carried out with 120 students which were grouped as experimental and control groups (Table 3).

Table 3. Demographic characteristics of students in the research group.

School	Groups	*N*		
		Young Woman	Young Man	Total
School A	Control (1)	17	13	30
	Control (2)	15	15	30
School B	Experimental (1)	19	11	30
	Experimental (2)	13	17	30

Due to the lengthy research period, the researcher's own activities and the need for a technical infrastructure, the schools involved in the research were determined by the easy-to-reach sampling method. The reason for choosing two different schools in the research was to ensure that the control group is not affected by the experimental procedures. In this context, it was made a point of choosing the experimental groups from the same school. In addition, in the classrooms except the groups participating in the research in the same school where the experimental procedures were carried out, the lessons were also taught with the support from the AR applications in order to avoid the feeling of exclusion and to benefit from the same activities. The researcher has done the activities in all classes in the school where the research was conducted.

Instrument and Experimental Process

Solar system and beyond success test (SSBST): The success test, which is formed of 20 questions, was developed by Kırıkkaya and Şentürk (2018) in order to measure the success of students for the subjects of "Solar System and Beyond" unit in the seventh grade. The test, with a confidence of .83, was evaluated over 100 points and details are as follows: the total number of correct questions was multiplied by five, where one point was given for each correct question and zero points for each wrong question. In this study, pre-test reliability coefficient for "Solar System and Beyond Success Test" was .70; and the post-test reliability coefficient was .77.

Students' motivation to science learning scale: In order to determine the motivation of primary school students for science learning, "Students' Motivation to Science Learning (SMSL)" scale, which was used in the study, was developed by Tuan and colleagues in 2005. The Turkish adaptation study was conducted by Yilmaz and Huyuguzel Çavaş (2007), and the reliability of the 5-point Likert type SMSL scale was found to be .87, and it was determined that the reliability level for the measurement tools that can be used in the researches was provided. In this research, reliability coefficient of pre-test was calculated as .82 for the SLMS scale and the final test was calculated as .89.

The experimental process was structured by the researchers with preparing lesson plans and activities. These lesson plans and activities were organized in accordance with the AR applications and in line with the achievements of the Science Education Program. The lesson plans prepared for the control groups were organized according to the activities envisaged in the science curriculum. In addition, in order to provide the balance between the research groups, it was found appropriate for the researcher to lecture the courses in both experimental and control groups. The basic steps followed in the experimental process are shown in Figure 2.

According to Figure 2, SSBST and SMSL Scale was applied as pre-test before the experimental process and AR technology was introduced to the experimental groups. It was necessary to inform students beforehand since they had not already met with AR applications and that these applications required technological skills. The research was conducted for a total of six weeks including four weeks experimental application, one week pre-test and one week post-test applications. In this process, activities including AR applications were carried out by researchers in the experimental groups. In the control groups, activities included in the curriculum were carried out (Figure 2).

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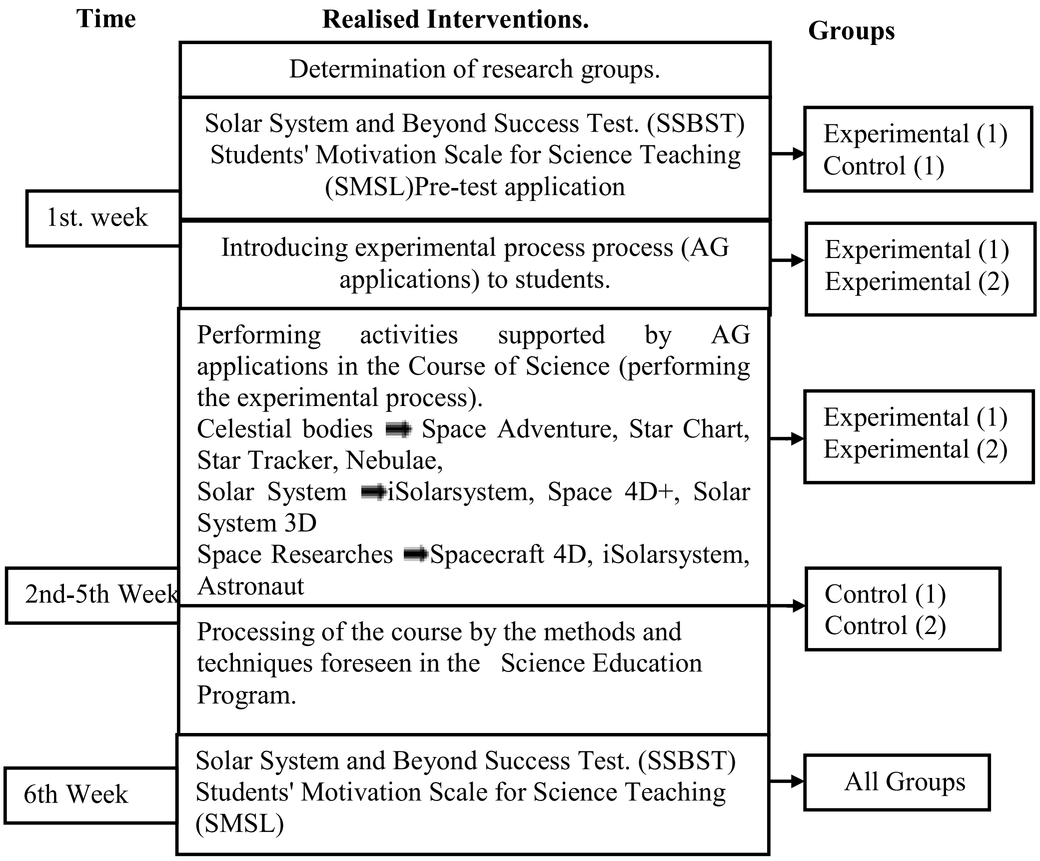

Figure 2. Procedures followed during experimental process.

"Sky Bodies" subject was taught with Space Adventure and Star Tracker AR applications in experimental groups. Students have been able to observe meteorite, meteor, meteor crater, star clusters (Ursa Minor, Ursa Major, and dragon), Orion nebula, Andromeda galaxy, Milky Way galaxy in 3D observation. Moreover, owing to this application, students had an opportunity to observe that the sun was a star and turned around its own axis and the stars were not as the one on the Turkish flag, but were spherical in shape.

The "Solar System" subject was taught with iSolarsystem and Space 4D AR applications in the experimental groups. One of the best achievements of these AR applications was that they showed very well that the planets are turning around the sun in a certain orbit. Instead of learning the features of the planets from the books in two-dimension, students have learned many of their features from the very beginning, such as proximity to the sun, satellite numbers, magnitude, rotation speeds around orbits, daily temperature differences and number of days to complete one revolution around the Sun. Moreover, students who studied the rotations of the Sun, the Earth and the Moon with the application of "iSolarsystem" AR, could better perceive the concepts of time such as a day, a year, a month.

"Space Research subject was taught with Spacecraft 4D and iSolarsystem AR applications in the experimental groups. Through these applications, students were able to observe the structure of the satellites in three dimensions via telescopes. During the experimental process, the students stated that they had heard the name of the Hubble Space Telescope. They added that they were observing the sky realistically for the first time, and they felt like astronauts and wanted to be astronauts. After four weeks of experimental process, "SSBST" and "SMSL" scales were applied to all groups as the post-test.

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Data Analysis

Cronbach's alpha coefficient was used for the calculating the reliability of the scales. For the determination of homogeneity and normality for data of obtaining from scales Levene Test, Shapiro Wilk, "Skewness and Kurtosis" were used. For the determination of the independent and combined effect of pre-test and experimental process, "Two-Way ANOVA for Independent Measurements"; for the interaction of pre-test and post-test in pre-test applied groups, "Two-way ANOVA for mixed measurements (ANOVA) and one-way analysis of covariance (ANCOVA) were used as statistical procedures. In addition, "Tukey Test" was used to determine the groups in which the significant difference was obtained, and the "Eta Squared" value was used to determine the effect size of statistical significance.

The data collected in the research were analyzed through SPSS 21 package program.

Research Results

In the analysis of the data obtained from the research, it was first examined whether the data could meet the basic assumptions of the parametric tests in order to decide which ones to be used. For this purpose, the Levene test was performed to determine whether the variances of the data were homogeneous (Table 4).

Table 4. Homogeneity test results for pre-test and post-test of experimental and control groups.

Data collection tool	Test	Levene Test	*df1*	*df2*	*p*
SSBST	Pre-Test	3.50	1	58	.07
	Post-Test	2.31	3	116	.08
SMSL	Pre-Test	.04	1	58	.84
	Post-Test	.51	3	116	.67

In Table 4, it is seen that the variance of the pre-test and post-test success scores of the experimental and control groups showed a homogeneous distribution (Pre-test, F=3.50, p>.05; Post-test, F=2.31; p>.05). Likewise, the variance of pre-test and post-test motivation scores of the experimental and control groups also showed a homogeneous distribution (Pre-test, F=.04; p>.05; Post-test, F=.51; p>.05). It was determined that the data showed a homogeneous distribution in terms of success and motivation variables via variance analysis. Then normality analysis, which is another assumption of parametric tests, was done. In this research, the normality analysis of the data was examined by considering the Skewness and Kurtosis values. According to Şimşek (2007), Skewness and Kurtosis values should also be considered while testing the assumption of normality. Tabachnick and Fidell (2013) indicated that the values of Skewness and Kurtosis should be within the range of +1.5 to -1.5, for admissibility limits. The values of Skewness and Kurtosis were given in Table 5 for pre-test and post-test measurement scores of this research.

Table 5. Values of Skewness and Kurtosis for pre-tests and post-tests of experimental and control groups.

Test		Groups	Skewness	Kurtosis	Test		Groups	Skewness	Kurtosis
SSBST	Pre Test	Experimental (1)	-.12	-.70	SMSL	Pre Test	Experimental (1)	-,54	-,70
		Control (1)	.36	-.79			Control (1)	-1.11	1.46
	Post Test	Experimental (1)	-.53	-.44		Post Test	Experiment (1)	-.33	-.59
		Control (1)	-.38	-.72			Control (1)	-.51	-.17
		Experimental (2)	.15	-.94			Experimental (2)	-.54	1.09
		Control (2)	-.27	-.99			Control (2)	-.99	1.41

Table 5 shows the values of Skewness and Kurtosis for the points that the research groups have taken from the data collection tools. Considering the values determined by Tabachnick and Fidell (2013), it was decided that

https://doi.org/10.33225/jbse/19.18.362

parametric tests should be used, because no dataset was found to exceed the range of +1.5/-1.5 and the data showed normal distribution.

Results Related to the First Question

The first question of the study was "Is there a significant difference between students in the experimental and control groups in terms of academic success and motivation upon application of the experimental procedure and pre-test stimulation?". That is to say, this question was related to examining the independent and combined effects of the experimental procedure and pre-test. For this purpose, "Two-way Analysis of Variance (2x2 ANOVA)" was conducted for independent measurements. Firstly, the arithmetic average and standard deviation of the SSBST post-test scores of the research groups were examined (Table 6).

Table 6. Arithmetic mean and standard deviation values for the SSBST post-test scores of experimental and control groups.

Data collection tool	Group	*N*	$\bar{X}$	*SD*
SSBST	Experimental (1)	30	84.33	12.23
	Control (1)	30	70.07	19.77
	Experimental (2)	30	81.33	13.19
	Control (2)	30	69.67	16.66

As seen in Table 6, the average SSBST of Experimental group (1) after the application was $\bar{X}_{post\text{-}test}$=84.33 and Control group (1) $\bar{X}_{post\text{-}test}$=70.07; Experimental group (2) $\bar{X}_{post\text{-}test}$=81.33 and Control group (2) $\bar{X}_{post\text{-}test}$=69.67. Two-way ANOVA was then conducted for the SSBST post-tests of the research groups (Table 7).

Table 7. Results of two-way analysis of variance for independent measurements for SSBST post-test scores of experimental and control groups.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*	η^2
Pre-test	86.70	1	86.70	.35	.56*	.00
Experimental Process	5044.03	1	5044.03	20.34	.0001	.15
Pre-test * Experimental Process	50.70	1	50.70	.20	.65*	.00
Total	34930.73	119				

**p<.05*

Without considering the experimental procedure, according to Table 7, there was no significant difference between the groups who received and who did not receive the pre-test ($F_{(1,116)}$=.35; p>.05). That is to say, the pre-test stimulation of the students in the Experimental (1) and Control (1) groups before the experimental process, did not lead to a significant difference in the success (SSBST) of the students in the research group. When the effect of the experimental process was examined, it was found that there was a significant difference between the experimental group students and control group students' academic success (SSBST) post-test scores ($F_{(1,116)}$=20.34; p<.05). In addition to the statistical significance in the difference between the groups, it could be said that the experimental process reflected a wide range of effects (η^2=.15). Tukey test was performed to understand between which groups that significant difference was. According to this test, SSBST post-test average of the Experimental group1 ($\bar{X}$=84.33) was significantly higher than the Control1 ($\bar{X}$=70.07) and Control2 groups ($\bar{X}$=69.67) (p<.05). SSBST post-test average of the Experimental group2 ($\bar{X}$=81.33) was significantly higher than the Control1 ($\bar{X}$=70.07) and Control2 ($\bar{X}$=69.67) groups (p<.05). According to this finding; it could be said that each Experimental group differs from the control group in terms of SSBST post-test averages. There was no difference between Experimental1 ($\bar{X}$=84.33) and Experimental2 ($\bar{X}$=81.33) groups in terms of SSBST post-test scores, as Control group1 ($\bar{X}$=70.07) and Control group2 ($\bar{X}$=69.67) (p>.05). These results showed that teaching the course with AR applications in experimental groups was effective in increasing the success of the students. Moreover, it was found that the experimental

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

procedure and pre-test had no significant combined effect on students' academic success ($F_{(1,116)}$=.20; p>.05). After conducting two-way analysis of variance for the success test, the arithmetic average and standard deviation values of the post-test scores of the science learning motivation of research groups were examined (Table 8).

Table 8. Arithmetic mean and standard deviation values of post-test SMSL scores of the experimental and control groups.

Data collection tool	Group	*N*	$\bar{X}$	*SD*
SMSL	Experimental (1)	30	136.30	13.94
	Control (1)	30	122.77	16.53
	Experimental (2)	30	131.47	15.35
	Control (2)	30	125.87	17.48

As seen in Table 8, SMSL for the Experimental group (1) was $\bar{X}_{post\text{-}test}$=136.30; Control group (1) was $\bar{X}_{post\text{-}test}$=122.77; the Experimental group (2) was $\bar{X}$post-test=131.47 and Control group (2) was $\bar{X}_{post\text{-}test}$ 125.87. Two-way analysis of variance was then performed for motivation post-tests of research groups (Table 9).

Table 9. Results of two-way analysis of variance for independent measurements of post-test SMSL scores of the experimental and control groups.

Source	Sum of Square	*df*	Mean of Square	*F*	*p*	η^2
Pre-Test	22.53	1	22.53	.09	.77*	.00
Experimental procedure	2745.63	1	2745.63	10.89	.0001	.09
Pre-test *Experimental Intervention	472.03	1	472.03	1.87	.17*	.02
Total	32486.79	119				

** p>.05*

According to Table 9, there was no significant difference between the SMSL averages of the groups which received the pre-test and did not receive the pre-test ($F_{(1,116)}$=.09; p>.05). That is to say that pre-test stimulation of the students before the experimental intervention did not lead to a significant difference in the motivation of the students in the experimental (1) and control (1) groups. When the effect of the experimental process was examined, it was found that the experimental group and the control group students had a meaningful difference between their post-test scores of SMSL and this difference reflected moderate effect ($F_{(1,116)}$=10.89; p<.05; η^2=.09). Tukey test was performed to see between which groups there were significant differences. Accordingly, the motivation post-test average of the Experimental group (1) ($\bar{X}$ = 136.30) was significantly higher than the Control (1) ($\bar{X}$=122.77) and Control (2) ($\bar{X}$=125.87) groups (p<0.05). The SMSL scale post-test average of the Experimental group (2) ($\bar{X}$=131.47) was significantly higher than the Control group (1) ($\bar{X}$=122.77) (p<0.05). According to this finding, it can be said that each experimental group differs from the control groups in terms of motivation post-test averages. In addition, there was no difference between SMSL scale post-test averages of Experimental (1) ($\bar{X}$=136.30) and Experimental (2) ($\bar{X}$=131.47) groups. Nonetheless, there was no difference between SMSL scale post-test averages of Control (1) ($\bar{X}$=122.77) and Control (2) ($\bar{X}$=125.87) groups (p>.05). These results showed that teaching the course with AR applications in experimental groups was effective in increasing the motivation of the students. Moreover, it was found that the experimental procedure and the pre-test had no significant common effect on students' motivation ($F_{(1,116)}$=1.87; p>.05).

Results Related to the Second Question

The second question of the research was declared as "Does the experimental procedure lead to a significant difference between academic success and motivation pre-test and post-test scores of the groups stimulated by the pre-test in the science course?". That is to say that, this question was intended to determine whether the experimental process is effective on groups received pre-test. For this purpose, "Two-way Analysis of Variance for

https://doi.org/10.33225/jbse/19.18.362

mixed measurements (2x2 ANOVA)" was carried out to determine whether the scores of the experimental (1) and control (1) groups received from the data collection tools significantly differed before and after the experimental procedure. Firstly, for the SSBST, the arithmetic mean and standard deviation values for the pre-test, post-test, and difference scores of experimental (1) and control (1) groups were examined.

Table 10. The arithmetic mean and standard deviation values for the SSBST pre-test, post-test, and difference scores of experiment1 and control1 groups.

Data collection tool	Group	*N*	Pre-Test		Post-Test		Difference Score	
			$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$	*SD*
SSBST	Experimental (1)	30	46.17	16.38	84.33	12.23	38.16	13.16
	Control (1)	30	41.83	20.41	70.07	19.77	28.24	14.45

As shown in Table 10, before the application, the SSBST score of Experimental group (1) was $\bar{X}_{pre-test}$=46.17; and after the application, it was $\bar{X}_{post-test}$=84.33. Before experimental process, the academic success score of the Control group (1) was $\bar{X}_{pre-test}$=41.83; while the post-$_{test}$ score was $\bar{X}_{post}$=70.07, after the application. In addition, the difference between the post-test score and the pre-test score of the Experimental group (1) was $\bar{X}_{post-test}$-$\bar{X}_{pre-test}$=38.16; while in the Control group (1), this difference was $\bar{X}_{post-test}$-$\bar{X}_{pre-test}$=28.24. Two-way analysis of variance for mixed measurements for academic success was then performed (Table 11).

Table 11. Results of two-way analysis of variance for mixed measurements for SSBST pre-test and post-test scores of experimental (1) and control (1) groups.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*	*η2*
Between-Subjects Factors	28668.80	59				
Experimental procedure	2594.70	1	2594.70	5.77	.02*	.09
Within-Subjects Factors	43262.00	60				
Difference between pre-test and post-test	33067.20	1	33067.20	202.85	.0001*	.78
Difference between pre-test and post-test *Experimental procedure	740.03	1	740.03	4.54	.04*	.07
Total	71930.80	119				

*p<,05

According to Table 11, it was seen that the SSBST scores of the experimental groups that had lessons with AR applications and the control groups that had only lessons with the activities in the program showed a significant difference after the experimental intervention, when compared to the start of the experiment; that is to say that the increase of the score of the experimental group was significantly higher than the control group ($F_{(1.,58)}$=4.54; p<.05). Considering that the difference scores were in favor of the experimental group (1) (Experimental group (1), $\bar{X}_{post-test}$-$\bar{X}_{pre\ test}$=38.16; Control group (1), $\bar{X}_{post-test}$-$\bar{X}_{pre-test}$=28.24); it could be said that the support of the program's activities with AR applications had a significant effect on the students' success on the "Solar System" subject and this effect was moderate (η^2=.07). Since the aim of this study was to test the effectiveness of AR applications in increasing students' success, the combined effect of measurement and experimental process factors was emphasized. In addition, the key factor tests of measurement and the experimental process were also examined. Accordingly, the difference between the total scores of the post-test and pre-test of the experimental and control groups was found to be significant ($F_{(1,58)}$=5.77, p<.05). According to this finding, it could be said that the support of the envisaged program's activities with AR applications had increased students' success and reflected a moderate effect (η^2=.09). Finally, there was a significant difference between SSBST post-test and pre-test scores of all students in experimental (1) and control (1) groups (without group distinction) ($F_{(1,58)}$ =202.85; p<.05). It could be stated that no matter which activities are applied, the students' success significantly increased throughout the experimental process, from the pre-implementation to the post-implementation, and this increase reflected a broad effect

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

(η^2=.78). Then, the arithmetic average and standard deviation values for SMSL pre-test, post-test and difference scores of Experimental (1) and Control (1) groups were examined (Table 12).

Table 12. The arithmetic mean and standard deviation values for SMSL pre-test, post-test, and difference scores of experimental (1) and control (1) groups.

Scale	Group	*N*	Pre-Test		Post-Test		Difference Score	
			$\bar{X}$	*SD*	$\bar{X}$	*SD*	$\bar{X}$	*SD*
SMSL	Experimental (1)	30	130.63	17.33	136.30	13.94	5.67	14.72
	Control (1)	30	121.70	18.94	122.77	16.53	1.01	21.69

As shown in Table 12, the SMSL scale score of Experimental group (1) was $\bar{X}_{pre\text{-}test}$=130.63 before the application, whereas $\bar{X}_{post\ test}$=136.30 after the experimental process. The success score of the Control group (1) was $\bar{X}_{pre\text{-}test}$=121.70, while the post- test was $\bar{X}_{post\text{-}test}$=122.77. In addition, while the difference between post-test and pre-test scores of experimental group (1) was $\bar{X}_{post\text{-}tes}$-$\bar{X}_{pretest}$=5.67, while the difference between post-test and pre-test scores of control (1) group was $\bar{X}_{post\text{-}test}$-$\bar{X}_{pre\text{-}test}$=1.01. Two-way ANOVA was then conducted for mixed measurements to determine students' motivation for science learning and is given in Table 13.

Table 13. Results of two-way analysis of variance for mixed measurements for SMSL pre-test and post-test scores of experimental (1) and control (1) groups.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*	*η2*
Between-Subjects Factors	25097.30	59				
Experimental procedure	3785.63	1	3785.63	10.30	.0001	.15
Within-Subjects Factors	11852.00	60				
Difference between pre-test and post-test	340.03	1	340.03	1.74	.19*	.03
Difference between pre-test and post-test *Experimental procedure	158.70	1	158.70	.81	.37*	.01
Total	36949.30	119				

According to Table 13, it can be seen that the SMSL scores of the experimental groups which were taught with the AR applications and the control groups which were taught according to the activities in the envisaged program did not show any significant difference after the experimental intervention ($F_{(1,58)}$=.81; p>.05). When the difference scores of the pre-test groups (Experimental group (1), $\bar{X}_{post\text{-}test}$-$\bar{X}_{pre\text{-}test}$=5.67; Control group (1), $\bar{X}_{post\text{-}test}$-$\bar{X}_{pre\text{-}test}$=1.01) are taken into account; there appears to be less motivation score changes in both groups after the application. The fact that SMSL was already high before the application, the student group was accustomed to the researcher, and it was very difficult to change the affective variables such as motivation within a period of six weeks, may be effective on having no significant difference. Although there was no significant difference, the increase in the difference scores in the experimental group shows that the AR applications are influential on the motivation of the students. The difference between the sum of the post-test and pre-test SMSL scores of the experimental and control groups was found to be significant ($F_{(1,58)=}$10.30; p<.05). According to this finding, it can be said that supporting the envisaged program's activities with AR applications increased the SMSL and reflects a wide effect (η^2=.15). Finally, there was no significant difference between the SMSL post-test scores and pre-test scores of all the students in the Experimental (1) and Control (1) groups (without group distinction) ($F_{(1,58)}$=1.74; p>.05). This is due to the fact that the difference between the sum of the post-test scores and the pre-test score of the groups which received the pre-test was very small. As noted above, it is difficult to change affective variables, such as motivation, in a short period of time, and the fact that students are already motivated in science lessons, even if they are not subjected to any treatment, these factors can be shown to cause no significant difference.

https://doi.org/10.33225/jbse/19.18.362

Results Related to the Third Question

The third question of the study was declared as "When pre-test is controlled, does the experimental procedure make a significant difference between the academic success and SMSL post-test scores of the students in the pre-test groups?". That is to say, it is intended to determine whether the experimental process is effective or not by controlling the pre-test applied to Experimental (1) and Control (1) groups. For this purpose, "Single Factor Covariance Analysis (ANCOVA)" was conducted. In the analysis of covariance, the effect on the dependent variable, namely pre-test, was determined as the variable to be controlled. Since the pre-test was checked on this count, the actual effect of the experimental process was tried to be found. For the covariance analysis, pre-test and post-test success scores of Experimental (1) and Control (1) groups showed homogenous and normal distribution and it was identified that there was a linear relationship between pre-test success scores (control variable) and post-test success scores (dependent variable) and that the slopes of the regression lines were equal. The post-test scores corrected according to the pre-test scores of the Experimental (1) and Control (1) groups were given in Table 14.

Table 14. Corrected mean scores calculated by considering the SSBST pre-tests of experimental (1) and control (1) groups.

Group	*N*	Mean	Corrected Mean
Experimental (1)	30	84.33	83.43
Control (1)	30	70.33	70.97

According to Table 14, when the effect of the pre-test was controlled, the average success score of the Experimental group (1) decreased from 84.33 to 83.43, and the success score of the control group (1) increased from 70.33 to 70.97. The results of the covariance analysis (ANCOVA) conducted to understand whether the differences between the adjusted average scores of the groups were meaningful, were given in Table 15.

Table 15. One-factor covariance analysis (ANCOVA) of the corrected post-test scores of SSBST of the experimental (1) and control (1) groups.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*	*η2*
Pre-test	3477.16	1	3477.16	16.26	.0001*	.22
Experimental procedure	2293.77	1	2293.77	10.72	.0001*	.16
Total	17964.31	59				

**p*<.05

According to the results of the covariance analysis (ANCOVA) in Table 15, when the SSBST pre-test scores were kept constant, it was found that there was a significant difference between the post-test scores of Experimental (1) and Control (1) groups ($F_{(1,57)}$=10.72; p<.05). These results showed that teaching the lecture with AR applications reflects a broad effect in increasing students' success (η^2=.16). In addition, when the effect of the control variable is examined in order to control the experimental process, it was seen that, there is a significant relation between pre-test and post-test ($F_{(1,57)}$=16.26; p<.05). Then for covariance analysis, it was determined that pre-test and post-test SMSL scores of Experimental (1) and Control (1) groups showed homogeneous and normal distributions; it was determined that there was a linear relationship between pre-test SMSL scores and post-test SMSL scores, and the inclination of regression lines was equal. It has been identified. The post-test scores, which were corrected according to pre-test scores of Experimental (1) and Control (1) groups, were given in Table 16.

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 16. Adjusted mean scores calculated by considering the pre-tests of SMSL of experimental (1) and control (1) groups.

Group	*N*	Mean	Corrected Mean
Experimental (1)	30	136.47	135.14
Control (1)	30	122.77	123.93

According to Table 13, when the effect of pre-test was controlled, the SMSL average of Experimental group (1) decreased from 136.47 to 135.14, and the SMSL average of Control group (1) increased from 122.77 to 123.93. The results of the covariance analysis (ANCOVA) on whether the difference between the adjusted average scores of the groups are meaningful, were given in Table 17.

Table 17. One-factor covariance analysis (ANCOVA) of SMSL scale on corrected post-test scores of experimental (1) and control (1) groups.

Source of Variance	Sum of Square	*df*	Mean of Square	*F*	*p*	η2
Pre-test	1297.27	1	1297.27	6.03	.02*	.10
Experimental procedure	1772.55	1	1772.55	8.24	.01*	.13
Total	15325.22	59				

**P < .05*

According to the covariance analysis (ANCOVA) result in Table 17, when the SMSL pre-test scores were kept constant, it was found that there was a significant difference between the post-test scores of Experimental (1) and Control (1) groups ($F_{(1,57)}$=8.24; p<.05).This suggests that teaching the course with AR applications reflects a moderate effect in increasing the motivation of students (η^2=.13). In addition, when the effect of the control variable was examined in order to control the experimental process, it was seen that, there is a significant relation between pre-test and post-test ($F_{(1,57)}$=6.03; p<.05).

Discussion

Solomon four-group model enabled to determine whether pre-testing, conducted prior to the start of the study, affects the academic success and motivation levels of students. Analysis results indicate that pre-testing did not have a significant effect on the academic success and motivation levels of the study groups. Similar results have been reported previously in the literature. Kartal (2013) has conducted a mixed study to examine the impact of microteaching on the development of pedagogical subject matter knowledge of science teacher candidates. Quantitatively, the study was based on Solomon four-group model and it was found that pre-testing did not influence the results significantly. Doğan (2017) conducted an experimental study using the Solomon four-group model to investigate the effect of teaching the subject "earthquake" via digital games in the social studies course on the academic success. The results indicated that there was a significant difference between the scores of experimental and control groups and pre-testing did not have a significant influence. All et al. (2017) conducted a study using the Solomon method on the evaluation of game-based learning and aimed to determine the advantages and disadvantages of pre-testing. As a result, it was determined that the pre-test had no effect and the game-based learning was effective. However, they emphasized that the means of pre-test groups were higher than those without pre-test and this finding should be taken into consideration in other studies.

Although there is no significant difference between the study groups in terms of pre-test, it is observed that the scores of the groups who are stimulated in terms of pre-test were higher when the final test scores of the students were taken into consideration. This can be explained by the fact that students are familiar with the structure and form of the questions. Previous studies conducted in our country using Solomon's Four Group Model were examined and it was observed that there was no clear information about the statistical operations to be used in the analysis of the data of this experimental pattern. For this reason, the studies from

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abroad, describing Solomon's Four Group Models, were taken into consideration. In this study, data obtained by using Solomon's Four-Group Model was analyzed rigorously and effort was made to transmit each step clearly to the reader. Solomon's four-group model, which allows the determination of whether the effect of pre-test sensitivity is meaningful, has strengthened the internal validity and external validity of the study. The lack of sensitivity to pre-test indicates that the changes in academic success and motivation of students are due to the AR technology.

According to the two-way analysis of variance to determine the effect of experimental process, it has been observed that the use of AR applications in the course process has a positive effect on students' academic success. One of the reasons for this positive effect is that the students encounter a new technology, find this technology interesting, and perceive it as a magic, due to AR technology and objects appearing on the paper in three dimensions. Previous studies also reported similar results that show that the use of AR increases the academic success of students. Sırakaya et al. (2018) reported that the use of AR applications in the seventh grade science class "Solar System" unit increased the academic success of students. Özarslan (2013) conducted a quasi-experimental study and found that the AR applications have a positive influence on the academic success of students. Baysan (2015) also reported that AR-supported learning environments increase the academic success of students. Küçük (2015) investigated the effect of mobile AR applications on the academic success and cognitive burden of medical students and found that the experimental group was more successful than the control group. Chiang et al. (2014) reported that mobile-supported AR applications increase academic success and motivation levels. Bacca et al. (2014) indicated that the AR is effective in improving the academic success. Chien et al. (2010) found that AR training strengthens spatial memory by providing an interactive interface that provides better anatomy learning. Maier et al. (2009) developed an AR program called "Augmented Chemical Reactions" to teach chemical reactions in chemistry lessons, which facilitated learning of the underlying processes and reduced the fear of chemistry.

The transfer of knowledge learned in the field of education in the direction of these studies is possible with the interactive environment presented to the students by the AR applications. As a matter of fact, new technologies integrated with education attract attention of students, activate them in the learning process, increase their occupation and motivation, and help them to understand the subject more easily. The fact that the world and the universe learning domain will be handled as the first units in the new 2017 Science Education Program shows that this unit is now given a higher emphasis. Previously, this unit was not given the attention it deserved due to it being the last unit and upcoming summer holiday. There is also a problem with the implementation of the activities envisaged in the program concerned with this unit. This is because there is no learning environment in which students can observe celestial objects. Textbooks are also insufficient in terms of visualizing the solar system in three dimensions. The teaching of astronomy, which is usually carried out in closed environments, is perhaps of interest to the students but obviously not very efficient. In this study, three-dimensional visualization of astronomical phenomena that cannot be applied in a typical class environment under normal conditions was achieved by the use of AR applications and thereby easier learning was provided by establishing the spatial link between these concepts in accordance with the cognitive period of seventh grade students.

When the effect of the experimental procedure on the motivation of the students is examined, it has been observed that instruction with AR applications affects the motivation of students at a significant level. There is also research in the literature showing that AR-enhanced learning increases the motivation of students and they enjoy using these applications. When the studies carried out in this context are examined, Tan and Lui (2013) found that using AR technology in teaching English vocabulary influenced the motivation of students positively. Di Serio et al. (2013) has stated that the attention and motivation of the students increased significantly and increase in their interaction with the learning environments has increased the motivation of the students when AR was used in the visual arts lesson. Similarly, Mahadzir and Phung (2013) found that the use of AR technology in books in foreign language teaching increased student motivation in vocabulary learning and Delello (2014) stated that when prospective science teachers used AR technology in the science class, they stated that it had a positive impact on the learning environment, increased students' motivation and provided ease of application.

It is also important to mention some limitations of the AR technologies used in the research. These limitations usually occur in the sense of follow-up, hardware, connection and improvement works are being done to overcome these limitations. Especially, late-detecting of the object on the application by camera, freezing of the camera and, the most importantly, excessive power consumption while the application is open

https://doi.org/10.33225/jbse/19.18.362

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

are the serious disadvantages. In order for AR technology to work properly, these technical problems need to be addressed and for this purpose, work-force and time are needed. Although AR faces some problems, it is possible to close this gap with the rapid development of digital and mobile technologies in recent years. Another limitation observed in the study was that in order for the applications to operate in a healthy manner and for each student to observe the objects in three dimensions, the study period in the experimental groups should be longer than in the control groups. The probable reason, why students in the experimental group finished their experience longer than others, could be that those students wish to observe the solar system in three-dimension more than once, as well as the time needed for the technological tools to operate and for the object recognition of the AR applications.

It is possible to say that mobile devices such as mobile phones and tablets are suitable environments for today's technology for AR experience. Mobile devices have advantages such as being portable, being widely used, being easily recharged and including software projects as Play-Store and Apple-Store. When the progress on mobile devices from past to present is examined, it is not wrong to predict that higher-capacity mobile devices will be produced in near future. Indeed, this indicates that new AR applications will likely to be designed in future. As such, mobile AR applications will become important material for educators. In this context, educators can make innovative choices in the classroom, including AR applications in addition to tools such as textbooks, board and chalk. Particularly, the AR technology will help students with weaker visual perception with their three-dimensional thinking skills. Thanks to the AR technology, real images of virtual objects are constructed, and stationary objects are transformed into multimedia, increasing the functionality of the learning environment. The increasing diversity of educational technologies gives educators important duties and roles in recognizing and using them effectively. For this reason, educators should follow the technological developments and try to use the most appropriate tools for their fields (Akkoyunlu, 2002). The body of literature in this field shows an increasing awareness of teachers, in particular towards the usage of AR technologies in education as well as an increasing number of research studies. Taking this study and similar studies as references, further studies on different topics and courses will be important to demonstrate the effectiveness of this technology in education.

Considering the compatibility of the use of mobile AR applications in teaching of other subjects in the science course, this technology may as well be used for the teaching of other units that are similarly difficult to visualize. The physical environments of schools should be designed in such a way that they can be utilized in the best possible way to benefit from AR applications. Classrooms should be donated with the basic tools and equipment required for this technology. In addition, studies using different methods and variables can be done with a larger sample group on the effective usability of this technology. Considering that developed countries aim to train individuals who are able to adapt technology rapidly, use technology efficiently and, most importantly, produce technology while creating their education programs (Can & Kaymakci, 2017), the successful integration of the AR technology into educational environments and the assessment of its advantages and disadvantages with these studies will be useful to give an idea to educators who want to use this technology. Finally, from the methodological point of view, it is suggested that further research is conducted to observe the effect of pre-test and experimental procedure due to the lack of studies conducted on the use of Solomon four-group model in science education in Turkey.

Conclusions

Thanks to the developments in mobile devices, the AR technology has been used in many sectors such as health, marketing, education, cinema, advertising and design. Thus, it has become possible to bring AR applications into the class and laboratory as teaching tools on mobile devices. In this study, AR applications are thought to be effective tools to provide access and visualization of concepts that are difficult to learn in astronomy. In this way, students will be able to discover the unknown properties of the universe and the inaccessible places of it. Thus, students will have the opportunity to experience and learn the universe in a realistic and better way. These experiences are expected to have a positive effect on their academic success and increase their motivation.

The general conclusion of this research is that using augmented reality applications in science teaching significantly contributes to the improvement of students' achievement and motivation. Since this research was conducted within the topic of Solar System and Beyond, the results cannot be generalized to the entire science teaching. Of course, the use of AG technology is not the best possible solution. For future research, it will be

https://doi.org/10.33225/jbse/19.18.362

useful to support science lessons with AG technology in order to have a significant effect on students' science achievement. This research was conducted by using "Solomon Four-Groups Design", which is one of the most powerful models that ensure internal and external validity at the same time. The Solomon four-groups design method enabled us to obtain more valid and reliable results since the effect of pre-test and intervention could be examined in detail. In the future, with the reporting of the successful integration of AG applications into educational environments and the obvious advantages on the educational environment, it is expected to give an idea and courage to educators who want to use this technology.

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Received: *February 19, 2019* Accepted: *May 06, 2019*

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https://doi.org/10.33225/jbse/19.18.362