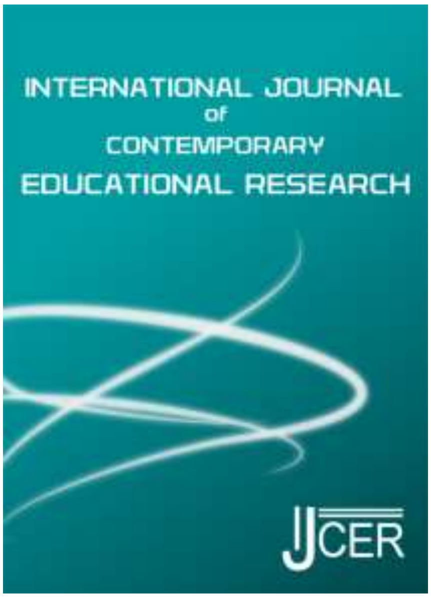

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Investigation of the Effectiveness of Augmented Reality and Modeling-based Teaching in "Solar System and Eclipses" Unit

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Abstract

This study was aimed to investigate the effectiveness of augmented reality and modeling-based teaching in the "Solar System and Eclipses" unit. The pretest-posttest quasi-experimental design model was used in this study. For three weeks, the "Solar System and Eclipses" unit of the Science course was taught to the experimental group using modeling-based teaching and augmented reality applications, and, in the control group, the existing science curriculum was followed. The study group consists of 22 students who were in the 6th grade in the 2020-2021 academic year in a secondary school affiliated with the Ministry of National Education. Data collection tools in this study were administered "Academic Achievement Test", "21st-Century Skills Scale", and "Augmented Reality Applications Attitude Scale". The application of augmented reality and modeling-based teaching in covering the "Solar System and Eclipses" unit was positively affected students' learning and increased their levels of success, improved the 21st-century skills and improved attitudes towards augmented reality applications. Studies on augmented reality applications and modeling-based teaching in different Science course units of different secondary school grades that will contribute positively to the literature are recommended.

Keywords: 21st-Century skills, Academic achievement, Augmented reality, Attitude, Modeling-based teaching method.

Introduction

In today's world, technology and innovation form an important balance. This leads to significant changes in the field of education, which is intertwined with technology, and enables the use of various technologies in the classroom. Accordingly, augmented reality technologies used in educational environments for effective learning have attracted a growing number of researchers (Korucu, Usta & Yavuzaslan, 2016). Augmented reality technology, which promises great potential in educational contexts and is becoming more widespread, is one of the augmented reality technologies that leads to successful outcomes by combining content and interactive three-dimensional elements (Azuma, 1997; Çavaş & Çulha, 2020; Luckin & Fraser, 2011).

Compared with conventional teaching methods, education supported by augmented reality has positively affected the learning process (Gecü-Parmaksız, 2017; Kerawalla, Luckin, Seljeflot & Woolard, 2006). The use of augmented reality technology in education contributes to the development of students in both affective and cognitive terms, making learning an efficient and interesting process, and allowing the stakeholders to enjoy themselves throughout (Tomi & Rambli, 2013; Wu, Lee, Chang & Liang, 2013). Learning via augmented reality mobile apps complements face-to-face education as well (Lin et al., 2013). In addition to these advantages, augmented reality positively contributes to learning by facilitating the comprehension and perception of concepts and helping them to be better structured in mind, especially in courses such as astronomy, science, and mathematics (Bujak et al., 2013; Yen, Tsai & Wu, 2013; Wojciechowski & Cellary, 2013). Research on augmented reality applications was found to positively contribute to success and understanding (Abdüsselam & Karal, 2012; Chiang, Yang & Hwang, 2014; Çankaya & Girgin, 2018; Fidan, 2018; Kırıkkaya & Şentürk, 2018; Sırakaya, 2015; Şentürk, 2018; Wang & Chi, 2012), motivation (Chiang et al., 2014; Çakır, Solak & Tan, 2015; Erbaş, 2016; Gül & Şahin, 2017; Ramazanoğlu & Solak, 2020; Sırakaya, 2015; Şentürk, 2018), attitudes toward AR technology applications (Ramazanoğlu & Solak, 2020; Şentürk, 2018), teaching concepts by reducing

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misconceptions (Sırakaya, 2015; Yen, Tsai & Wu, 2013), self-efficacy beliefs (Fidan, 2018), and avoidance of anxiety in learning (Şentürk, 2018).

Görecek-Baybars and Çil (2019) found in their studies that secondary school students do not have a scientific thinking model. Therefore, it was found that the development of students' intellectual activities is a very important priority (Ayvacı, Bebek, Atik, Keleş & Özdemir, 2016). As a result, there is a need to design the learning process in such a way that mental activities are emphasized and appropriate learning methods are used. One of the effective methods that can be used in developing students' mental models is model-based teaching (Gobert & Buckley, 2000; Ünal-Çoban, 2009). The modeling-based teaching method dates to the 1980s (Halloun, 2011) refers to the model using analogical reasoning and achieving structural equality (Gentner & Smith, 2012). Modeling based teaching allows students to understand subjects by making relationships and solving the problems they have. It allows students to understand subjects by making relationships, solving their problems, and developing ideas about these subjects with scientific methods (Lehrer, & Schauble, 2005; Schwarz, & White, 2005; Windschitl, Rose, Stalkfleet, & Smith, 2008). The modeling-based teaching process is a process that allows students to think about the subject using their preliminary knowledge, connect with daily life or apply it to another situation (Ünal-Çoban, 2009). This process improves the student's comprehension level, shortens the learning moment, and strengthens the validity of the mental models created by the student (Güldal & Doğru, 2018). Modeling-based teaching enables students to improve their problem-solving skills (Aztekin & Taşpınar-Şener, 2015), conceptual understanding (Ünal-Çoban, Kocagül-Sağlam & Solmaz, 2016), comprehension levels (Güldal & Doğru, 2018), skills such as thinking and analysis (Ayvacı & Bülbül, 2020; Günbatar & Sarı, 2005), and ability to share ideas and resource utilization (Zorlu & Sezek, 2016). Strengthening the modeling competencies of individuals is necessary to improve the scientific literacy levels of the generation that is growing up in the 21st century.

To keep up with the developing world and its needs, the growing generation is expected to have skills that are known as 21st-century skills. According to Cheng and Tsai (2013) with Tekdal & Saygıner (2016), the augmented reality applications utilized in science education aim to facilitate student development in every aspect of learning evolve day by day, and there is an increasing trend of using such technologies in educational environments. There are relevant studies carried out with students (Ateş, 2018; Demirel, 2019; Sırakaya, 2015; Yıldırım, 2020) and pre-service teachers and active teachers (Timur & Özdemir, 2018) that address the utilization of augmented reality applications within the scope of the science course. It is seen that in these studies, abstract and complex concepts that cannot be observed or applied in daily life were taught using the said technologies and positive results were obtained (Abdüsselam & Karal, 2012; Sırakaya, 2015). In terms of this use, augmented reality applications, just like modeling-based teaching, can be used in covering topics that students need to associate with daily life based on their prior knowledge or apply in the context of another topic. To understand a subject that covers science well, it is important that they correctly configure the basic concepts of that subject in their minds by associating them with each other (Tokatlı, 2010). In their study, Görecek-Baybars and Çil (2019) examined students' mental models in the solar system. They found that middle school students do not have a scientifically mental model. The importance of using effective learning methods using technology and mental processes is becoming increasingly important in astronomy education, including the solar system and solar and lunar eclipses (Bujak et al., 2013; Namdar & Küçük, 2018; Zhang, Sung, Hou & Chang, 2014). Accordingly, the application was made in the unit "Solar System and Eclipses". In cases where it is difficult to develop three-dimensional content and applications for use in teaching, modeling-based teaching applications can be utilized. So, when the relevant studies are examined, it is understood that modeling-based teaching and augmented reality applications complement each other. Accordingly, this study investigated whether the use of augmented reality and modeling-based instructional applications in covering the "Solar System and Eclipses" unit of the 6th- grade Science course has contributed to students' learning, improved their 21st century skills, and influenced their attitudes toward augmented reality.

Method

The quasi-experimental pretest-posttest design model was used in this study. In this model, a pretest and posttest are carried out to the experimental and control groups previously created via the random method (Creswell, 2008; Fraenkel & Wallen, 2000). In this study, an experimental (EG) and a control (CG) group were formed by randomly assigning branches as either the experimental or control groups. Pretests were administered to the experimental and control groups before starting the application. The augmented reality and modeling-based teaching method was applied to the experimental group, and the current learning method was applied to the control group. At the end of the application, posttests were administered to the experimental and control groups. In this study, data collection tools were used Academic Achievement Test (AAT), 21st-Century Skills Scale (21CSS) and Augmented Reality Applications Attitude Scale (ARAAS). In this study, the Academic Achievement Test (AAT) was administered to examine academic achievement, the 21st-Century Skills Scale (21CSS) was administered to examine the effects on the field-specific skill variable (21st century skills) of science education, and the

Augmented Reality Applications Attitude Scale (ARAAS) was administered to examine attitudes toward augmented reality to students. The experimental design of the study is shown in Table 1.

Table 1. The experimental design of this study

Groups	Pre-Tests	Implementation	Post-Tests
Experiment (EG)	AAT 21CSS	Modeling-based Teaching and Augmented Reality (AR) Applications	AAT 21CSS
Control (CG)	ARAAS	The Existing Method of The Science Course Curriculum	ARAAS

The Study Group

The study group consists of students in the 6th grade in the 2020-2021 academic year in a secondary school affiliated with the Ministry of National Education in western Anatolia (Aegean region). Two 6th-grade branches constituted the participant groups, one of which was randomly assigned as the experimental group and the other as the control group. The study was carried out with the participation of 22 students, 11 (8 females and 3 males) of which were in the experimental group and 11 (7 females and 4 males) in the control group. In the study, 20.75% of the target population was taken as the sample. Statistical power analysis was performed using the G*Power program to determine the sample size. According to this power analysis, when the power analysis was analyzed at an 80% confidence interval and p=0.05 significance level, it was calculated that the minimum sample number was 18 students. In this sample consisting of 22 students, the power of the study was calculated as 0.867. In this context, it has been concluded that the sample represents the universe according to the G*Power program.

Data Collection Tools

Academic Achievement Test (AAT)

In the study, the “Academic Achievement Test” (AAT) for the "Solar System and Eclipses" unit of the Science course, which was prepared in a way that is suitable for the 6th-grade students, was utilized. The AAT was developed by Yeşiltepe (2019) and consists of 25 multiple choice questions covering the "Solar System and Eclipses" unit of the Science course. The KR20 reliability coefficient of the AAT was calculated as 0.85 (Yeşiltepe, 2019). In this study, the AAT was taken by 22 students who completed the Solar System and Eclipses unit. The obtained data showed that the KR20 reliability coefficient of the AAT was 0.80.

21st-Century Skills Scale (21CSS)

The “21st-Century Skills Scale” (21CSS) used in the study was developed by Kang, Kim, Kim and You (2012) and it was adapted into Turkish by Karakaş (2015). The original scale consists of 32 items with three main domains (cognitive, affective, and sociocultural) and 21 sub-domains. The scale is a five-point Likert-type scale. Karakaş (2015) calculated the reliability coefficients of the scale as 0.77 for the "Cognitive" domain, 0.70 for the "Affective" domain, and 0.67 for the "Sociocultural" domain. The reliability coefficient (Cronbach's Alpha) of the scale was found to be 0.92 in this study. For the factors of the scale the values 0.80 for the domain "Cognitive", 0.80 for the domain "Affective" and 0.81 for the domain "Sociocultural" were calculated.

Augmented Reality Applications Attitude Scale (ARAAS)

The “Augmented Reality Applications Attitude Scale” (ARAAS) developed by Küçük, Yılmaz, Baydaş and Göktaş (2014) was utilized to examine the attitudes towards augmented reality technology. ARAAS is a five-point Likert scale that consists of three factors (Use Satisfaction, Use Anxiety, and Use Willingness) and 15 items. The internal consistency reliability coefficient of ARAAS was found to be 0.83. The coefficients of the factors, on the other hand, were found to be 0.862 for the "Use Satisfaction" factor, 0.828 for "Use Anxiety", and 0.644 for "Use Willingness" (Küçük et al, 2014). In this study, the internal consistency reliability coefficient of ARAAS was found to be 0.89. This value was found to be 0.79 for the "Use Satisfaction" factor, 0.77 for "Use Anxiety", and 0.67 for the "Will to Use".

Pilot Application

In this study, before starting to work on the effectiveness of augmented reality technology within the scope of science course, interviews were conducted with 18 science teachers working under the Ministry of National Education in the 2019-2020 academic year for the needs analysis. Before the application, brief information about augmented reality technology was given to the science teachers. Interviews with science teachers emphasized that augmented reality applications should be used during the lessons and applied together with active teaching methods. In addition, the science teachers mainly stated that AR applications should be made in the units of "Solar System and Eclipses", "Solar System and Beyond, Sun", "Earth and Moon", which are the first units related to astronomy in the curriculum. Apart from these units, they also stated the subjects of "Structure of the Cell", "Organelles", "Atomic Models", "Systems in Our Body", "Natural Phenomena", "Living World", "DNA and Genetic Code". Expert views were taken from three science teachers for the activities developed within the scope of the application. The activities were organized for expert views.

Implementation Process in The Experimental and Control Groups

The implementation phase of the study lasted for five weeks. For three weeks, the "Solar System and Eclipses" unit of the Science course was taught to the experimental group using modeling-based teaching and augmented reality applications, and, in the control group, the existing science curriculum was followed. Before implementation, AAT, 21CSS, and ARAAS were administered to the students in the experimental and control groups as pre-tests. To apply the modeling-based teaching method in the experimental group, worksheets for each of the sub-topics in the “Solar System and Eclipses” unit were prepared by the researchers in the light of the modeling-based teaching cycle proposed by Ünal-Çoban (2009). Several resources were used while preparing the working papers (M). AR applications were also carried out with the said working papers. The AR applications with students were carried out using the Space 4D+ and Space AR apps procured by the researchers (In this study, the photos of AR applications are given in the appendix). In addition, the exercises related to the topic in the textbook were given to students as homework. The teaching of the next sub-topic started after reviewing all assignments. The same method was followed in all topics of the unit. On the other hand, the control group was taught the topic using the conventional teaching methods. After implementation, the AAT, the 21CSS, and the ARAAS were administered as posttests. After the post-tests were administered, the augmented reality applications were repeated for two-course hours with the control group.

Data Analysis

The sample size of 30 and above is no longer a prerequisite for normal distribution. Studies have proved the sample that it will provide normal distribution if it is less than 30 or not if it is greater than 30 (Chang et al., 2008; Warner, 2008, as cited in Cevahir, 2020). The skewness and kurtosis values were first looked at for normal distribution control of the scores obtained from the AAT, 21CSS and ARAAS. If the ratio of skewness and kurtosis values to standard errors remains between -1.96 and +1.96, distribution is considered normal (Can, 2014). Skewness and Kurtosis must also be between -1 and +1 (Morgan et al., 2004). The skewness and kurtosis values of the data obtained from the 21CSS and ARAAS are between -1 and +1, the skewness value/skewness standard error ratio is between the standard error, and the kurtosis value/kurtosis standard error ratio is between -1.96 and +1.96. However, it is seen that the skewness and kurtosis values obtained from AAT are not between -1 and +1.

Table 2. Shapiro-Wilk analyze for pre-tests and post-tests

Tests		Groups	Shapiro-Wilk Statistics	df	p
AAT	Pre-test	EG	0.900	11	0.184
		CG	0.856	11	0.050
	Post-test	EG	0.862	11	0.061
		CG	0.919	11	0.308
21CSS	Pre-test	EG	0.952	11	0.667
		CG	0.938	11	0.500
	Post-test	EG	0.929	11	0.400
		CG	0.979	11	0.962
ARAAS	Pre-test	EG	0.979	11	0.959
		CG	0.941	11	0.530
	Post-test	EG	0.946	11	0.594
		CG	0.915	11	0.277

EG: Experiment Group, CG: Control Group

Table 2 shows that the data obtained from the pretests and posttests of the AAT did not have a normal distribution according to the normality analysis ($p<.05$). The Mann-Whitney U test was carried out to analyze the scores obtained from the pretests and posttests of the AAT. It was found that the data obtained from the pretests and posttests of 21CSS and ARAAS did have a normal distribution according to the normality analysis ($p>.05$). Conditions for covariance analysis of the data obtained from 21CSS and ARAAS were examined (Can, 2014). The students in the experimental and control group are all different. The data obtained in 21CSS and ARAAS have a normal distribution. When the interaction of the pretests of experimental and control groups was examined, it was determined that regression accuracy did not differ by groups, and there was no significant difference between regression slopes (p=0.248 for 21CSS, p=0.366 for ARAAS; p>0.05). It can be said that the data obtained in 21CSS and ARAAS have a normal distribution and provide the conditions for covariance analysis. In light of this finding, an ANCOVA analysis was conducted using the pretest and posttest results of 21CSS and ARAAS.

Results

The descriptive analysis and results of the Mann-Whitney U test performed on the AAT pre-test and post-test applied to the students in the experimental and control groups are given in Table 3.

Table 3. Mann Whitney U test and descriptive analysis of AAT

AAT	Groups	n	X	SD	Mean Rank	Total Rank	U	p
Pre-test	EG	11	15.82	5.19	13.14	144.50	42.500	0.235
	CG	11	12.91	4.04	9.86	108.50		
Post-test	EG	11	20.64	3.67	14.32	157.50	29.500	0.040
	CG	11	16.64	4.01	8.68	95.50		

Table 3 shows that average pre-test and post-test AAT scores are higher for students at EG than for students at CG. To Table 3, determine whether this situation is statistically significant, the Mann-Whitney U test was performed on the scores obtained from the AAT pre-tests and post-tests. When the Mann-Whitney U Test results of the AAT pre-test scores were analyzed, no statistically significant difference was found between the experimental and control groups, U=42.50, p=0.235. As for the Mann-Whitney U test results of the AAT post-test scores, it is seen that there is a statistically significant difference in the AAT post-test scores in favor of the students in the experimental group, U=29.50, p=0.040.

The descriptive statistics regarding the 21CSS pre-test and post-test scores are given in Table 4.

Table 4. Descriptive statistics of 21CSS

	Groups	N	Mean Pre-Test	Mean Post-Test	Mean Corrected Post-Test
21CSS	EG	11	126.91	132.28	134.22
	CG	11	130.36	130.82	128.87
Cognitive	EG	11	46.28	49.18	49.45
	CG	11	47.00	47.55	47.28
Affective	EG	11	42.09	42.91	43.63
	CG	11	43.27	42.09	41.38
Sociocultural	EG	11	38.55	40.18	41.07
	CG	11	40.09	41.18	40.29

To determine Table 4, the effects of the teaching methods used in the experimental and control groups on students' 21st century skills, and to understand whether the difference between the scores obtained in the 21CSS post-tests was statistically significant, an ANCOVA analysis of the corrected means of the 21CSS post-tests was conducted. Accordingly, 21CSS pre-test results were taken as the covariant, method as the independent variable and post-test results as the dependent variable. The data obtained from the ANCOVA analysis are shown in Tables 5 and 6.

Table 5. ANCOVA analysis results of 21CSS

Source	Sum of Squares	df	Mean of Squares	F	p	η2
21CSS(Pre-test)	3711.571	1	3711.571	308.63	0.000	0.942
Method	154.391	1	154.391	12.852	0.002	0.403
Error	228.247	19	12.013			
Total	384644.000	22				

The results of the ANCOVA test in Table 5 show that there is a statistically significant difference between the 21st century skills [$F_{(1-22)}$= 12.852, p<.05]. The statistically significant difference in the ANCOVA analysis is found in favor of the experimental group. The η2 (eta squared), which is the variance ratio explained by the effect of the independent variables, is 0.403 for the applied experimental variable. This means that approximately 40% of the variance in the study's dependent variable, the post-test scores of the 21CSS, is explained by the independent variable, the applied method.

Table 6. ANCOVA analysis results of factors of 21CSS

Factors	Source	Sum of Squares	df	Mean of Squares	F	p	η2
Cognitive	Pre-test	330.373	1	330.373	84.837	0.000	0.817
	Method	25.771	1	25.771	6.618	0.019	0.258
	Error	73.990	19	3.894			
	Total	51878.000	22				
Affective	Pre-test	497.718	1	497.718	224.621	0.000	0.922
	Method	27.227	1	27.227	12.287	0.002	0.393
	Error	42.100	19	2.216			
	Total	410281.000	22				
Sociocultural	Pre-test	573.938	1	573.938	212.425	0.000	0.918
	Method	3.265	1	3.265	1.208	0.285	0.060
	Error	51.335	19	2.702			
	Total	37041.000	22				

When Table 6 is examined, it can be deduced that there is no statistically significant difference between the scores of the students in the experimental and control groups in terms of the "Sociocultural" factor [$F_{(1-22)}$= 1.208, p>0.05]. On the other hand, it was determined that there were statistically significant differences between the scores of the students in the experimental and control groups in terms of the "Cognitive" and "Affective" factors [Cognitive: $F_{(1-20)}$= 6.618, p<0.05; Affective: $F_{(1-20)}$= 12.287, p<0.05]. It can be observed that statistically significant differences in the ANCOVA analysis results in terms of the "Cognitive" and "Affective" factors are in favor of the experimental group. The η2 (eta square) for the applied experimental variable is 0.258 for the "Cognitive" factor and 0.393 for the "Affective" factor, which are the variance ratios explained by the effect of the independent variables. This means that about 26% of the variance in the post-test scores of the factor "Cognitive", which is the dependent variable, and about 39% of the variance in the post-test scores of the factor "Affective", which is the independent variable, are explained by the teaching method used.

Descriptive analysis results of the ARAAS pre-test and post-test scores of the students in experimental and control groups are given in Table 7.

Table 7. Descriptive statistics of ARAAS

	Groups	n	Mean Pre-Test	Mean Post-Test	Mean Corrected Post-Test
ARAAS	EG	11	53.64	62.91	66.68
	CG	11	58.73	57.27	53.50
Use Satisfaction	EG	11	25.45	29.82	31.66
	CG	11	28.82	26.09	24.25
Use Anxiety	EG	11	20.45	24.64	25.53
	CG	11	22.36	23.00	22.10
Use Willingness	EG	11	7.73	8.45	8.38
	CG	11	7.55	8.18	8.26

Table 7 shows that the ARAAS post-test results were higher than the pre-test results both in the experimental and control groups. To determine the effects of the teaching methods used in the experimental and control groups on students' attitudes toward augmented reality applications and to understand whether the difference between the scores obtained in the AARAS posttests was statistically significant, an ANCOVA analysis of the corrected means of the ARAAS posttests was conducted. Accordingly, ARAAS pre-test results were taken as the covariant, method as the independent variable, and post-test results as the dependent variable. The data obtained from the ANCOVA analysis are shown in Tables 8 and 9.

Table 8. ANCOVA analysis results for ARAAS

Source	Sum of Squares	df	Mean of Squares	F	p	η2
ARAAS(Pre-test)	1202.933	1	1202.933	132.761	0.000	0.875
Method	757.719	1	757.719	83.625	0.000	0.815
Error	172.157	19	9.061			
Total	80990.000	22				

The ANCOVA test results in Table 8 show that there is a statistically significant difference between the ARAAS scores of the students in the experimental and control groups [$F_{(1-22)}$= 83.625, p<.05]. The statistically significant difference in ANCOVA analysis is observed to be in favor of the experimental group. The η2 (eta squared), which is the variance ratio explained by the effect of the independent variables, is 0.815 for the applied experimental variable. This means that about 81% of the variance in ARAAS post-test scores, the dependent variable in this study, is explained by the method used, the independent variable.

Table 9. ANCOVA analysis results for factors of ARAAS

Factors	Source	Sum of Squares	df	Mean of Squares	F	p	η2
Use Satisfaction	Pre-test	199.305	1	199.305	28.000	0.000	0.596
	Method	219.720	1	219.720	30.869	0.000	0.619
	Error	135.240	19	7.118			
	Total	17603.000	22				
Use Anxiety	Pre-test	106.822	1	106.822	14.321	0.001	0.430
	Method	55.467	1	55.467	7.436	0.013	0.281
	Error	141.724	19	7.459			
	Total	12744.000	22				
Use Willingness	Pre-test	26.497	1	26.497	15.799	0.001	0.454
	Method	0.077	1	0.077	0.046	0.833	0.002
	Error	31.867	19	1.677			
	Total	1581.000	22				

Table 9 shows that there is no statistically significant difference between the ARAAS scores of the students in the experimental and control groups in terms of the "Use Willingness" factor [$F_{(1-22)}$= 0.046, p>0.05]. Statistically, significant differences were detected between the ARAAS scores of the students in the experimental and control groups in terms of the "Use Satisfaction" and "Use Anxiety" factors [Use Satisfaction: $F_{(1-22)}$= 30.869, p<0.05; Use Anxiety: $F_{(1-22)}$= 7.436, p<0.05]. It was seen that these statistically significant differences are in favor of the experimental group. The η2 (eta squared), which is the variance ratio explained by the effect of the independent variables, is 0.619 for “Satisfaction with Use” and 0.281 for “Using Anxiety” factors. This means that approximately 62% of the variance in the post-test scores of the "Use Satisfaction" factor and 28% of the variance in the post-test scores in the "Use Anxiety" factor, which are the dependent variables, are explained by the applied teaching method, which is the independent variable.

Conclusions and Discussion

In this study, which investigated the effects of using augmented reality and modeling-based instruction in the treatment of the solar system and eclipses unit in science on student learning, 21st century skills, and attitudes toward augmented reality, the following results were obtained and discussed in comparison to the relevant literature.

The use of augmented reality (AR) and modeling-based teaching in covering the "Solar System and Eclipses" unit of the Science course has positively affected students' learning and increased their success levels. This finding shows parallelism with the findings of studies in which the students in the groups where the topics are taught using the modeling-based learning method are found to be more successful than the students in the other group where conventional teaching methods are used (Bilal, 2010; Çetinkaya 2017; Demirçalı, 2016; Ergün & Sarıkaya, 2019; Gülcü & Taşçi, 2020; Kılıçoğlu, 2019; Tombul, 2019; Ünal-Çoban, 2009; Zorlu, 2016b). However, there are also studies in which the modeling-modeling-based modeling-based teaching method did not significantly impact the academic achievement levels of students in the group to which this method was applied (Arslan, 2013; Çavumirza, 2018).

The relevant studies in the literature conclude that teaching using models supports the construction and development of mental models, improves the ability to visualize concepts in the mind and contributes to the concretization of concepts (Demirhan, 2015; Pekmezci, 2017), positively affects conceptual development and reduces misconceptions (Birinci & Apaydın, 2016; Bozdemir-Yüzbaşıoğlu & Sarıkaya, 2019; Ünal-Çoban, Kocagül-Sağlam & Solmaz, 2016), improves the retention of information (Çavumirza, 2018; Ergün & Sarıkaya, 2019; Gülcü & Taşçi, 2020), and helps to connect scientific concepts to real life (Güldal & Doğru, 2018). Considering that concepts related to the Science course are difficult to perceive, using models in teaching is of great importance (Çevik-Ezberci, 2018). In addition, studies are showing that the use of models positively affects students' ability to create mental models (Clement & Steinberg, 2002; Kurnaz, 2011; Ogan-Bekiroğlu, 2007). In their studies, Arslan (2013) and Kılıçoğlu (2019) concluded that the use of models positively impacted students' ability to create mental models. Gülcü and Taşçi (2020) also stated in their studies that covering scientific concepts using the modeling-based teaching method positively impacts the cognitive structure of students. Similarly, Taylor, Barker and Jones (2003) revealed that due to the difficulty of comprehending astronomy concepts, the lessons carried out with modeling-based activities ensure the formation and development of mental models and positively contribute to students' academic performance success.

The existence of mixed findings in the literature on the impact of the use of augmented reality technology applications on academic success can be explained by the fact that the studies focused on different courses, units, or grade levels. The findings of the relevant studies that investigated the use of AR applications in education concluded that such applications positively impact the success levels of students in the Science course (Akçayır & Akçayır, 2016; Cai, Chiang & Wang, 2013; Chiang et al., 2014; Chu, Chen, Yang & Lin, 2016; Çakır, Solak & Tan, 2015; Çankaya & Girgin, 2018; Demirel, 2019; Fidan, 2018; Gecü-Parmaksız, 2017; Ibanez, Di Serio, Villaran & Kloos, 2014; Küçük, Kapakin & Göktaş, 2016; Peder-Alagöz, 2020; Shelton & Hedley, 2002; Şentürk 2018; Türksoy, 2019; Yıldırım, 2020). AR applications were also found to reduce misconceptions and contribute positively to the comprehension of concepts (Shelton & Hedley, 2002; Sırakaya, 2015; Yen et al., 2013), as well as and help to concretize concepts (Abdüsselam & Karal, 2012). However, there are also studies thatsome studies found no difference between the experimental and control groups in terms of the impacts of the use of AR applications on students' academic success levels (Cai et al., 2013; Erbaş, 2016). In their study, Yen, Tsai and Wu (2013) used simulation-based augmented reality-assisted teaching in an undergraduate lecture on the phases of the Moon and did not observe any positive changes in the academic success levels of students.

AR used for educational purposes facilitates access to practical information and provides students with an interesting and enjoyable learning experience (Lin et al., 2013). The use of AR in teaching science enables presenting important points and concepts visually, multidimensional, and in association with real life, and therefore helps to comprehend information immediately and retain it easily (Klopfer & Sheldon, 2010; Klopfer & Squire, 2008). Also, the modeling-based teaching method used in this study enables following a sequence that improves the students' effective comprehension levels by improving their ability to create mental models (Güldal & Doğru, 2018). Students ' mental activity is stimulated by switching from mental schemas to a given state. Therefore, students must make strong connections between existing information and new concepts (Krathwohl & Anderson, 2010). Aydoğan-Yenmez (2017) reinforced the modeling-based teaching method with technology in her study and obtained positive results, which are also consistent with the results of our study.

Findings obtained from the 21CSS showed that the students in the experimental group were better achievers than those in the control group. This result can be considered as evidence that the use of AR and the modeling-based teaching method in the experimental group improves the 21st century skills of the students in the said group. The relevant studies in the literature also show that the use of the model-based teaching method improves the 21st century skills of the students, scientific process skills, critical thinking skills, and understanding of scientific methods (Batı, 2014; Nelson & Davis, 2012; Ünal-Çoban, 2009; Zorlu, 2016b; Zorlu & Sezek, 2020). A literature review also manifests that AR applications for educational purposes improve students' 21st-century skills and scientific process skills (Papanastasiou, Drigas, Skianis, Lytras & Papanastasiou, 2019; Sanabria & Arámburo-Lizárraga, 2017). The AR applications and -based modeling-based teaching method used in our study invoked a positive change in the students' skill levels. This finding is similar to the finding of Sanabria and Arámburo-Lizárraga (2017) that such applications provide students with multiple sensory learning opportunities, thus positively contributing to the development of problem-solving and creative thinking skills, as well as creativity, with the help of technology. It is established that with the integration of the modeling-based teaching method and AR applications in education, improvements have been observed in terms of concept comprehension, abstract expression perceptibility, and class enjoyment. In fact, when reviewing the literature, it appears that one of the main reasons for adopting the adoption of the modeling-based teaching method is that students can easily grasp the concepts through various process flows related to their daily lives, which enhances their cognitive development (Ünal-Çoban, 2009). The innovative AR technology was utilized to create a simultaneous and dynamic relationship between the real world and the virtual world and comprehend the concepts in a multi-dimensional manner, which ultimately helps to obtain 21-st century skills.

Findings related to the “Cognitive” and “Affective” factors of the 21CSS revealed that the students in the experimental group were better achievers than those in the control group. Based on this finding, it is possible to claim that the AR applications and the modeling-based teaching method utilized in the experimental group improved the 21st-century skills of the students in this group in cognitive and affective terms. The cognitive domain consists of the "knowledge management", "knowledge structuring", "information use", and "problem-solving" sub-domains. In contrast, the affective domain consists of “self-identity”, “self-worth”, “self-direction”, “self-responsibility”, and “social membership” sub-domains (Karakaş, 2015). The motivation and attitude of a person to a given situation are important in helping students gain affective characteristics, which are sub-domains of 21st-century skills (Ersoy, 2012). It was found that the increase in student desire and willingness, invoked by modeling-based teaching, has reflected positively to the AR attitude scale. It is safe to say that this positively impacts students' affective characteristics as well. Dunleavy, Dede and Mitchell (2009) claim that augmented reality-based tools help to increase students' motivation and willingness to learn. Thus, students can manage their own learning processes and play an active role in them, which contributes to improving students’ affective domain skills. In such cases, improvement is observed especially in the "self-management" and "self-responsibility" sub-domains. These tools are also an effective tool in students' learning processes with relatively low levels of success (Cai et al., 2013).

Cognitive skills play an important role in the students' learning. Metacognitive strategies come to the fore within the context of 21st-century skills, along with cognitive schemas and arrangements (Veenman, Van Hout-Wolters, & Afflerbach, 2006). The modeling-based teaching method helps students use their existing mental schemas to form new mental schemas that are appropriate for the new situation (Gobert & Pallant, 2004). With -based modeling-based science teaching, the scientific method is explained based on scientific process skills (Develaki, 2007), and the students' scientific process skills are strengthened (Ünal-Çoban, 2009). The fact that our study was reinforced with AR applications made the learning environment and students' motivation more significant for the study, consequently positively impacting students' cognitive skills. In the light of this information, it can be clearly seen that mentioned methods contribute positively to developing students’ cognitive skills. The inclusion of applications that can contribute to and improve the students' cognitive skills in curricula will help to maintain the critical thinking disposition throughout generations (Aybek, 2007). Utilizing tools such as project development, model building, and experiments positively affect the cognitive development of students (Aygün, 2019).

Findings showed no difference between the students in the experimental and control groups regarding the Sociocultural factor of the 21SCC. The sub-domains of the "socio-cultural" domain of the 21st-century skills are “Social Membership”, “Social Sensitivity”, “Socialization Ability”, and “Social Performance (fulfillment)” (Karakaş, 2015). It is thought that there were no positive changes in the experimental group in terms of the socio-cultural domain as there was no situation in which students could act as a group or one of the students could step up as the leader and because of the fact that the intra-team communication was weak and, cooperative learning could not be achieved effectively. Consequently, it can be said that the students did not show any significant improvement in the social domain as the group members did not work in cooperation. Individuals must interact with other people to develop their social skills. During learning, students' interactions with each other affect their success levels; so, it can be said that they are bound to learn from each other (Karataş, Cengiz & Çalışkan, 2018; Özünal, 2017). The collaborative learning model can be actively utilized to develop the students to develop the students' socio-cultural skills in the experimental group. In the cooperative learning model, it is important for the students to be active within the group. In this model, individuals commit to each other and aim to learn together; by providing a socially active environment, students are expected to improve their social behaviors on an individual level (Johnson, Johnson, & Holubec, 1994). Accordingly, the dynamics of the relationships between the students in the group should be stimulated by using the cooperative learning model. Thanks to the positive impacts of this model on the attitudes towards the Science course, the students' collaborative skills can be strengthened (Zorlu, 2016a; Zorlu, 2016b).

ARAAS findings show that the students in the experimental group were better achievers than those in the control group. Based on this finding, it is possible to claim that the AR applications and the modeling-based teaching method utilized in the experimental group improved students’ attitudes towards AR applications. The positive or negative attitude of an individual towards an object, situation, or an escalating situation is called attitude (Türker & Turanlı, 2008). Student academic success is a phenomenon that can be explained based on affective characteristics. It is important to elaborate on these characteristics in examining student success (Kan & Akbaş, 2005). Affective characteristics are one of the important factors that have an impact on students’ learning. In examining students' affective characteristics, attitudes and anxiety levels can be scrutinized. Positive affective behavior is of significant importance for permanent learning to take place and individuals to be successful (Etlioğlu & Tekin, 2020). Studies have shown that there is a significant relationship between the academic success levels of students and their affective attitudes (Coşkun, 2018; Fidan, 2018; Şentürk, 2018). The affective attitudes of the students towards the Science course after the utilization of AR applications in teaching were examined, and the positive findings were examined vis-à-vis the relevant studies in the literature (Akkiren, 2019; Demirel, 2017; Erbaş 2016; Onbaşılı, 2018; Sırakaya, 2015; Sırakaya & Alsancak-Sırakaya, 2018). Relevant studies concluded that the integration of AR applications in the learning process helped decrease students' use anxiety and increase use satisfaction and use willingness.

Recommendations

- We believe that further studies on the use of augmented reality applications and modeling-based teaching in different Science course units of different secondary school grades will positively contribute to the literature. It is also thought that carrying out different studies on modeling-based teaching supported with technologies other than augmented reality will positively contribute to the literature.
- Since the application of modeling-based teaching methods and augmented reality contributes positively to student success and 21st century skills, these teaching methods can be incorporated into the process, and their contributions can be benefited in the science teaching process.
- The study concluded that the desire to use augmented reality was at a high level of students in the experimental and control group. From this point of view, it is thought that the use of augmented reality and similar application at all class levels of science courses will contribute to the attitudes of the students to the courses.
- There has been no development of 21st-century skills in the socio-cultural dimension in our work. The general characteristics of the cooperative learning model are not included, even if heterogeneous cooperative groups are made that apply modeling-based teaching methods with increased reality. It is thought that the general characteristics of the cooperative learning model with heterogeneous cooperative groups in these and similar applications will be included in the process and will enable the development of socio-cultural skills. It is recommended that future studies be carried out with heterogeneous cooperative groups instead of individuals or groups.
- Finally, student textbooks can be used to prepare activities to be used in augmented reality-supported modeling-based teaching, which would be compatible with the curriculum.

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There aren't any potential conflicts of interest.

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References

Abdüsselam, M. S., & Karal, H. (2012). 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.

Akçayır, M., & Akçayır, G. (2016). University students' opinions about use of augmented reality in foreign language teaching. *Erzincan University Journal of Education Faculty, 18*(2), 1169-1186. https://doi.org/10.17556/jef.86406

Arslan, A. (2013). *The effects of modeling based science and technology teaching on understanding, memorization, creativity and mental models of primary school students.* (Publication No. 333880) [Master's thesis, Akdeniz University, Antalya]. Databases of National Thesis Center of the Council of Higher Education.

Ateş, A. (2018). *7 th grade science and technology course "Structure of the substance and pure substances" on augmented reality created using technology learning material effect on academic achievement.* (Publication No. 531780) [Master's thesis, Niğde Ömer Halisdemir University, Niğde]. Databases of National Thesis Center of the Council of Higher Education.

Aybek, B. (2007). Konu ve beceri temelli eleştirel düşünme öğretiminin öğretmen adaylarının eleştirel düşünme eğilimi ve düzeyine etkisi. *Journal of Çukurova University Institude of Social Sciences, 16*(2), 43-60.

Aydoğan-Yenmez, A. (2017). The effects of technology on the mathematical modeling. *Adıyaman University Journal of Social Sciences,* 26, 602-646. https://doi.org/10.14520/adyusbd.306665

Aygün, D. (2019). *Investigation of the scientific skills development process of 7th year students through project, model, experiment.* (Publication No. 601360) [Master's thesis, Bursa Uludağ University, Bursa]. Databases of National Thesis Center of the Council of Higher Education.

Ayvacı, H. Ş., Bebek, G., Alper, A., Keleş, C. B., & Özdemir, N. (2016). Investigate of the students' mental models in modeling process: The case of cell. *Dicle University Journal of Ziya Gökalp Faculty of Education,* 28, 175-188. https://doi.org/10.14582/DUZGEF.711

Ayvacı, H. Ş., & Bülbül, S. (2020). Identifying modeling skills of secondary school students. *Cumhuriyet International Journal of Education, 9*(4), 1000-1028. http://dx.doi.org/10.30703/cije.581752

Aztekin, S., & Taşpınar-Şener, Z. (2015). The content analysis of mathematical modelling studies in Turkey: A meta-synthesis study. *Education and Science, 40*(178), 139-161. http://dx.doi.org/10.15390/EB.2015.4125

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators and Virtual Environments, 6*(4), 355-385. https://doi.org/10.1162/pres.1997.6.4.355

Batı, K. (2014). *The effectiveness of modeling based elementary science education; It's effects on students' views about nature of science and critical thinking abilities.* (Publication No. 383791) [Doctoral dissertation, Hacettepe University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Bilal, E. (2010). *Effects of electricity instruction by modeling on conceptual understanding, academic achievement and epistemological beliefs.* (Unpublished doctoral dissertation). (Publication No. 265534) [Doctoral dissertation, Dokuz Eylül University, İzmir]. Databases of National Thesis Center of the Council of Higher Education.

Birinci, O., & Apaydın, Z. (2016). Effect of modelling learning on sound related conceptual development of prımary school 4th grade students. *International Journal of Turkish Education Sciences, 2016*(7), 22-43.

Bozdemir-Yüzbaşıoğlu, H., & Sarıkaya, R. (2019). The effect of model-based learning approach on students' development of mental model about microorganisms subject. *Kalem International Journal of Education and Human Sciences, 9*(2), 357-384. https://doi.org/10.23863/kalem.2019.131

Bujak, K. R., Radu, I., Catrambone, R., MacIntyre, B., Zheng, R., & Golubski, G. (2013). A psychological perspective on augmented reality in the mathematics classroom. *Computers & Education,* 68, 536-544. https://doi.org/10.1016/j.compedu.2013.02.017

Cai, S., Chiang, F. K., & Wang, X. (2013). Using the augmented reality 3D technique for a convex imaging experiment in a physics course. *International Journal of Engineering Education, 29*(4), 856-865.

Can, A. (2014). *SPSS ile bilimsel araştırma sürecinde nicel veri analizi*. Ankara: Pegem Akademi.

Cevahir, E. (2020). *SPSS ile nicel veri analizi rehberi*. İstanbul: Kibele.

Cheng, K. H., & Tsai, C. C. (2013). Affordances of augmented reality in science learning: Suggestions for future research. *Journal of Science Education and Technology,* 22, 449-462. http://dx.doi.org/10.1007/s10956-012-9405-9

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

Chu, H. C., Chen, J. M., Yang, K. H., & Lin, C. W. (2016). Development and application of a repertory grid-oriented knowledge construction augmented reality learning system for context-aware ubiquitous learning. *International Journal of Mobile Learning and Organisation, 10*(1-2), 40-60.

Clement, J. J., & Steinberg, M. S. (2002). Step-wise evolution of mental models of electric circuits: A" learning-aloud" case study. *The Journal of the Learning Sciences, 11*(4), 389-452.

Çoşkun, M. (2018). *The impact of the teaching supported with mobile application and augmented reality on motivation and anxiety about science lesson, attitude towards astronomy, and academic success of students.* (Publication No. 524836) [Master's thesis, Hatay Mustafa Kemal University, Hatay]. Databases of National Thesis Center of the Council of Higher Education.

Çakır, R., Solak, E., & Tan, S. S. (2015). Effect of teachıng englısh vocabulary wıth augmented realıty technologıes on students' performances. *Gazi Journal of Education Sciences, 1*(1), 45-58.

Çankaya, B., & Girgin, S. (2018). The effect of augmented realıty technology on the academıc success of scıence course. *Journal of Social and Humanities Sciences Research (JSHSR),* 5(30), 4283-4290.

Çavumirza, E. (2018). *The effect of model based science teaching on 8th grade students' achievement, critical thinking tendencies, attitudes and concept learning.* (Publication No. 516233) [Master's thesis, Sakarya University, Sakarya]. Databases of National Thesis Center of the Council of Higher Education.

Çetinkaya, M. (2017). Effect of personalized blended learning environments arranged on the basis of modeling to achievement in science education. *Ordu University Journal of Social Science Research, 7*(2), 287-296.

Çevik-Ezberci, E. (2018). *Investigation of the grounded mental models in star subject of prospective science teachers by mathematical algorithms.* (Publication No. 530199) [Doctoral dissertation, Kastamonu University, Kastamonu]. Databases of National Thesis Center of the Council of Higher Education.

Demirçalı, S. (2016). *The effects of model based science education on students' academic achevement, scientific process skills and mental model devolopment: the sample of 7th grade unit of "The solar system and beyond: The puzzle of space".* (Publication No. 450167) [Doctoral dissertation, Gazi University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Demirel, G. (2019). *The effect of a science lecture taught using augmented reality applications on 7th grade students' academic achievement and attitudes toward augmented reality applications.* (Publication No. 575389) [Master's thesis, Gazi University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Demirhan E. (2015). *The effect of designing 3D models on prospective science teachers' academic achievement, problem solving skills, scientific creativity and perceptions about the process.* (Publication No. 381752) [Doctoral dissertation, Marmara University, İstanbul]. Databases of National Thesis Center of the Council of Higher Education.

Develaki, M. (2007). The model-based view of scientific theories and the structuring of school science programmes. *Science & Education, 16*(7), 725-749. https://doi.org/10.1007/s11191-006-9058-2

Erbaş, Ç. (2016). *The effects of mobile augmented reality applications on students' academic achievement and motivation.* (Publication No. 426260) [Master's thesis, Süleyman Demirel University, Isparta]. Databases of National Thesis Center of the Council of Higher Education.

Ergün, A., & Sarıkaya, M. (2019). The effect of model based learning on the academic success and conceptual understanding of middle-school students on the particulate nature of matter. *Electronic Journal of Social Sciences, 18*(72), 2059-2075. https://doi.org/10.17755/esosder.539584

Etlioğlu, M., & Tekin, M. (2020). The mediating role of student's curiosity and anxiety in the relationship between student attitude and academic achievement in electronic learning. *The Journal of Selçuk University Social Sciences Institute, 43*(34), 34-48.

Fidan, M. (2018). *The impact of problem-based science teaching assisted with augmented reality applications on academic achievement, retention, attitude and belief of self-efficacy.* (Publication No. 504726) [Doctoral dissertation, Bolu Abant İzzet Baysal University, Bolu]. Databases of National Thesis Center of the Council of Higher Education.

Fraenkel, J. K, & Wallen, N. E. (1996). *How to design and evaluate research in education* (third edition). New York: McGraw-Hill, Inc.

Gecü-Parmaksız, Z. (2017). *Augmented reality activities for children: a comparative analysis on understanding geometric shapes and improving spatial skills.* (Publication No. 475084) [Doctoral dissertation, Middle East Technical University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Gentner, D., & Smith, L. (2012). Analogical reasoning. In V. S. Ramachandran (Ed.) *Encyclopedia of Human Behavior* (Second edit.) (pp. 130-136). Oxford, UK: Elsevier

Gobert, J. D., & Buckley, B. C. (2000). Introduction to model-based teaching and learning in science education. *International Journal of Science Education, 22*(9), 891-894. https://doi.org/10.1080/095006900416839

Gobert, J. D., & Pallant, A. (2004). Fostering students' epistemologies of models via authentic model-based tasks. *Journal of Science Education and Technology, 13*(1), 7-22. https://doi.org/10.1023/B:JOST.0000019635.70068.6f

Görecek-Baybars, M., & Çil, M. (2019). Secondary school students' mental models about "Solar System". *Journal of Social Sciences of Mus Alparslan University, 7*(37), 37-46. https://doi.org/10.18506/anemon.521940

Gülcü, M., & Taşçi, G. (2020). The examination of the learning proceses by modeling the biology subject of primary school students. *Anatolian Journal of Teacher, 4*(1), 75-97. https://doi.org/10.35346/aod.726943

Güldal, C. G., & Doğru, M. (2018). The effect of model-based science teaching on 6th class students' science anxiety and their associations between the science concepts and daily life. *Journal of Research in Education and Society, 5*(2), 187-211.

Günbatar, S., & Sarı, M. (2005). Developing models for difficult and abstract concepts in electrics and magnetism. *Gazi University Gazi Faculty of Education Journal, 25*(1), 185-197.

Ibanez, M. B., Di Serio, A., Villaran, D., & Kloos, C. D. (2014). Experimenting with electromagnetism using augmented reality: Impact on flow student experience and educational effectiveness. *Computers & Education,* 71, 1-13. https://doi.org/10.1016/j.compedu.2013.09.004

Johnson, R.T., Johnson, D. W., & Holubec, E. J. (1994). *New circles of learning: cooperation in the classroom and school,* Alexandra, VA, USA: Association for Supervision & Curriculum Development (ASCD).

Karakaş, M. M. (2015). *Investigation of the eight - grade secondary school students' levels of 21st century skills in science education.* (Publication No. 391151) [Master's thesis, Eskişehir Osman Gazi Üniversitesi University, Eskişehir]. Databases of National Thesis Center of the Council of Higher Education.

Karataş, F. Ö., Cengiz, C., & Çalışkan, B. (2018). The effect of instruction based on cooperative learning environment supported with worksheets on students' academic achivement. *Research and Experience Journal (REJ), 3*(1), 1-16.

Kan, A., & Akbaş, A. (2005). Lise öğrencilerinin kimya dersine yönelik tutum ölçeği geliştirme çalışması. *Mersin University Journal of the Faculty of Education, 1(*2), 227-237.

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.

Krathwohl, D. R., & Anderson, L. W. (2010). Merlin C. Wittrock and the revision of Bloom's taxonomy. *Educational Psychologist, 45*(1), 64-65. https://doi.org/10.1080/00461520903433562

Küçük, S., Kapakin, S., & Göktaş, Y. (2016). Learning anatomy via mobile augmented reality: Effects on achievement and cognitive load. *Anatomical Sciences Education, 9*(5), 411-421. https://doi.org/10.1002/ase.1603

Küçük, S., Yılmaz, R. M., Baydaş, Ö, & Göktaş, Y. (2014). Augmented reality applications attitude scale in secondary schools: Validity and reliability study. *Education and Science, 39*(176) 383-392. https://doi.org/10.15390/EB.2014.3590

Kerawalla, L., Luckin, R., Seljeflot, S., & Woolard, A. (2006). "Making it real": Exploring the potential of augmented reality for teaching primary school science. *Virtual Reality, 10*(3-4), 163-174. https://doi.org/10.1007/s10055-006-0036-4

Kılıçoğlu, F. (2019). *The effects of the teaching intervention including models and modelling on students' achievement of "the particulate structure of matter" subject and their mental models of atom*. (Publication No. 589238) [Doctoral dissertation, Trabzon University, Trabzon]. Databases of National Thesis Center of the Council of Higher Education.

Kırıkkaya, E. B., & Şentürk, M. (2018). The impact of using augmented reality technology in the solar system and beyond unit on the academic achievement of the students. *Kastamonu Education Journal*, *26*(1), https://doi.org/181-189. 10.24106/kefdergi.375861

Kurnaz, M. A. (2011). *The effect of learning environments based on model-based learning approach to mental model development about energy subject.* (Publication No. 300383) [Doctoral dissertation, Karadeniz Technical University, Trabzon]. Databases of National Thesis Center of the Council of Higher Education.

Lehrer, R., & Schauble, L. (2005). Developing Modeling and Argument in the Elementary Grades. In T. A. Romberg, T. P. Carpenter, & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 29–53). Lawrence Erlbaum Associates Publishers.

Lin, T. J., Duh, H. B. L., Li, N., Wang, H. Y., & Tsai, C. C. (2013). An investigation of learners' collaborative knowledge construction performances and behavior patterns in an augmented reality simulation system. *Computers & Education,* 68, 314-321. https://doi.org/10.1016/j.compedu.2013.05.011

Luckin, R., & Fraser, D. S. (2011). Limitless or pointless? An evaluation of augmented reality technology in the school and home. *International Journal of Technology Enhanced Learning, 3*(5), 510-524. https://doi.org/10.1504/ijtel.2011.042102

Ministry of National Education [MoNE], (2018). *İlköğretim kurumları fen bilimleri dersi öğretim programı [Primary education institutions science course curriculum]*. Ankara: Board of Education.

Nelson, M. M., & Davis, E. A. (2012). Preservice elementary teachers' evaluations of elementary students' scientific models: an aspect of pedagogical content knowledge for scientific modeling. *International Journal of Science Education, 34*(12), 1931-1959. https://doi.org/10.1080/09500693.2011.594103

Ogan-Bekiroğlu, F. (2007). Effects of model-based teaching on pre-service physics teachers' conceptions of the moon, moon phases, and other lunar phenomena. *International Journal of Science Education, 29*(5), 555-593. https://doi.org/10.1080/09500690600718104

Onbaşılı-İzgi, Ü. (2018). The effect of augmented reality practices on the attitudes of primary school students towards augmented reality practices and science motivation. *Ege Journal of Education, 19*(1), 320-337. https://doi.org/10.12984/egeefd.390018

Özünal, S. (2017). The effects of collaborative learning approach on students' academic success in teaching geography subjects. *Bolu Abant İzzet Baysal University Journal of Faculty of Education, 17*(2), 850-867. https://doi.org/10.17240/aibuefd.2017.17.30227-326602

Papanastasiou, G., Drigas, A., Skianis, C., Lytras, M., & Papanastasiou, E. (2019). Virtual and augmented reality effects on K-12, higher and tertiary education students' twenty-first century skills. *Virtual Reality,* 23, 425-436. https://doi.org/10.1007/s10055-018-0363-2

Peder-Alagöz, Z. B. (2020). *The effects of the mobile augmented reality applications on secondary school 7th grade students' anxiety towards science and academic achievements.* (Publication No. 628124) [Masters' thesis, Gazi University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Pekmezci, A. (2017). *The change of the sixth grade students' mental models regarding the human respiratory system.* (Publication No. 456609) [Masters' thesis, Ondokuz Mayıs University, Samsun]. Databases of National Thesis Center of the Council of Higher Education.

Ramazanoğlu, M., & Solak, M. Ş. (2020). Attitudes of secondary school students towards the use of augmented reality applications in education: Sample of Siirt province. *Kastamonu Education Journal*, *28*(4), 1646-1656.

Sanabria, J. C., & Arámburo-Lizárraga, J. (2017). Enhancing 21st century skills with AR: Using the gradual ımmersion method to develop collaborative creativity. *Eurasia Journal of Mathematics, Science and Technology Education, 13*(2), 487-501. https://doi.org/10.12973/eurasia.2017.00627a

Schwarz, C. V., & White, B. Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognition and instruction, 23*(2), 165-205. https://doi.org/10.1207/s1532690xci2302_1

Sırakaya, M. (2015). *Effects of augmented reality applications on students' achievement, misconceptions and course engagement.* (Publication No. 419423) [Doctoral dissertation, Gazi University, Ankara]. Databases of National Thesis Center of the Council of Higher Education.

Sırakaya, M., & Alsancak-Sırakaya, D. A. (2018). The effect of augmented reality use in science education on attitude and motivation. *Kastamonu Education Journal, 26*(3), 887-905.

Şentürk, M. (2018). *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, sicence and technology attitude.* (Publication No. 494794) [Masters' thesis, Kocaeli University, Kocaeli]. Databases of National Thesis Center of the Council of Higher Education.

Taylor, I., Barker, M., & Jones, A. (2003). Promoting mental model building in astronomy education. *International Journal of Science Education, 25*(10), 1205-1225. https://doi.org/10.1080/0950069022000017270a

Tekdal, M., & Saygıner, Ş. (2016). Augmented reality use ın educational meaning: A content analysis study. *10th International Computer and Instructional Technologies Symposium (ICITS)*, 16-18 May 2016, Rize, Turkey.

Timur, B., & Özdemir, M. (2018). Teachers' views on the use of augmented reality environments in science education. *International Journal of Turkish Education Sciences, 10*, 62-75.

Tokatlı, F. R. (2010). *The effect of conceptual change approach, cooperative learning and computer assisted instruction on students' science achievement*. (Publication No. 274809) [Masters' thesis, Sakarya University, Sakarya]. Databases of National Thesis Center of the Council of Higher Education.

Tombul, S. (2019). *The effect of computer supported instruction and modelling of subject of astronomy on 7th grade students on some learning products.* (Publication No. 594221) [Masters' thesis, Ordu University, Ordu]. Databases of National Thesis Center of the Council of Higher Education.

Tomi, A. B., & Rambli, D. R. A. (2013). An interactive mobile augmented reality magical playbook: Learning number with the thirsty crow. *Procedia Computer Science,* 25, 123-130. https://doi.org/10.1016/j.procs.2013.11.015

Türker, N. K., & Turanlı, N. (2008). Developing an Attitude Scale for Mathematics Education Courses. *Gazi University Journal of Gazi Educational Faculty, 28*(3),17-29.

Türksoy, E. (2019). *The effect of teaching methods integrated with augmented reality and online materials on achievement and retention in science lesson: Mixed design.* (Publication No. 600062) [Doctoral dissertation, Burdur Mehmet Akif Ersoy University, Burdur]. Databases of National Thesis Center of the Council of Higher Education.

Ünal-Çoban, G. (2009). *The effects of model based science education on students? conceptual understanding, science process skills, understanding of scientific knowledge and its domain of existence: The sample of 7th grade unit of light.* (Publication No. 231558) [Doctoral dissertation, Dokuz Eylül University, İzmir]. Databases of National Thesis Center of the Council of Higher Education.

Ünal-Çoban, G., Kocagül-Sağlam, M., & Solmaz, G. (2016). The effect of model based teaching on metacognitive awareness, attitudes and conceptual understanding. *The Western Anatolia Journal of Educational Sciences (WAJES), 7*(13), 61-104.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning, 1*(1), 3-14. https://doi.org/10.1007/s11409-006-6893-0

Windschitl, P. D., Rose, J. P., Stalkfleet, M. T., & Smith, A. R. (2008). Are people excessive or judicious in their egocentrism? A modeling approach to understanding bias and accuracy in people's optimism. *Journal of Personality and Social Psychology, 95*(2), 253. https://doi.org/10.1037/0022-3514.95.2.253

Wojciechowski, R., & Cellary, W. (2013). Evaluation of learners' attitude toward learning in ARIES augmented reality environments. *Computers & Education,* 68, 570-585. http://dx.doi.org/10.1016/j.compedu.2013.02.014

Wang, C. H., & Chi, P. H. (2012). Applying augmented reality in teaching fundamental earth science in junior high schools. In *Computer applications for database, education, and ubiquitous computing* (pp. 23-30). Springer, Berlin, Heidelberg.

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. https://doi.org/10.1016/j.compedu.2012.10.024

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, 165-173. https://doi.org/10.1016/j.sbspro.2013.10.322

Yeşiltepe, K. (2019). *The effect of the ARCS motivation model on the academic success and motivation of students in the solar system and eclipses unit of science course.* (Publication No. 552905) [Masters' thesis, Niğde Ömer Halisdemir University, Niğde]. Databases of National Thesis Center of the Council of Higher Education.

Yıldırım, İ. (2020). *The effect of augmented reality applications in science education on academic achievement and retention of 6th grade students.* Publication No. 635866) [Masters' thesis, Eskişehir Osmangazi University, Eskişehir]. Databases of National Thesis Center of the Council of Higher Education.

Zhang, J., Sung, Y. T., Hou, H. T., & Chang, K. E. (2014). The development and evaluation of an augmented reality-based armillary sphere for astronomical observation instruction. *Computers & education*, *73*, 178-188.

Zorlu, F. (2016a). *Investigation of effectiveness of application of solomon research design to cooperative learning model in teaching science lesson.* (Publication No. 433830) [Doctoral dissertation, Atatürk University, Erzurum]. Databases of National Thesis Center of the Council of Higher Education.

Zorlu, F., & Zorlu, Y. (2022). The investigation of preservice science teachers' analogical reasoning skills from thinking skills. *Thinking Skills and Creativity,* 43, 1-14. https://doi.org/10.1016/j.tsc.2021.100981

Zorlu, Y. (2016b). *Effects of activities based on modeling learning method and cooperative learning model of students in elementary science and technology.* (Publication No. 429615) [Doctoral dissertation, Atatürk University, Erzurum]. Databases of National Thesis Center of the Council of Higher Education.

Zorlu, Y., & Sezek, F. (2016). The investigation of effects to learning together method with modeling based learning method on constructivist learning environment. *Ekev Akademi Dergisi,* 68, 415-430.

Appendix-Photos of AR applications