Article History
Received: 30.05.2022
Received in revised form: 07.09.2022
Accepted: 17.09.2022
Article Type: Research Article

International Journal of Contemporary Educational Research (IJCER)

www.ijcer.net

The Impact of Using Model and Augmented Reality Technology on Students' Science Achievement, Motivation, and Interest Levels

Şeyma Nur Sivri [1], Eylem Eroğlu [2]

[1]Ministry of National Education, 0000-0001-5906-9246
[2]Bolu Abant İzzet Baysal University, 0000-0003-1487-1264

To cite this article:

Sivri, S. N. & Eroğlu, E. (2022). The ımpact of using model and augmented reality technology on students' science achievement, motivation, and ınterest levels. *International Journal of Contemporary Educational Research, 9*(3), 633-648. https://doi.org/10.33200/ijcer.1123204

International Journal of Contemporary Educational Research

Volume 9, Number 3, September 2022, 633-648 ISSN: 2148-3868

The Impact of Using Model and Augmented Reality Technology on Students' Science Achievement, Motivation, and Interest Levels

Şeyma Nur Sivri[1], Eylem Eroğlu[2*]
[1]Ministry of National Education
[2]Bolu Abant İzzet Baysal University

Abstract

In this study, it was aimed to investigate the effects of modelling and the materials designed with augmented reality technology on the academic success of students, their motivation, and their interest levels towards the science course. The study was conducted in 6th grade science units on "Support and Movement Systems" and "Systems in Our Body". In the study, a quasi-experimental design with a pre-test and post-test control group was applied. The study was carried out with three groups: the control group, the augmented reality experimental group, and the modeling experimental group. The research sample consists of a total of 66 students studying at a public middle school in the Küçükçekmece district of İstanbul province during the 2020-2021 academic year. To collect data, a 30-item Science Achievement Test, a 23-item Science Motivation Scale, and a 27-item Science Interest Scale were applied. The Kruskal-Wallis test was applied for multiple comparisons, and Mann-Whitney U tests were carried out for post-hoc comparisons. For intragroup comparisons, Wilcoxon Signed Ranks tests were applied. According to the results of the study, it was concluded that the use of augmented reality and modeling techniques in the science course had a statistically significant effect on the academic success, motivation, and interest of the students towards the science course.

Keywords: Augmented Reality, Modeling, Science Achievement, Interest, Motivation

Introduction

Rapid changes experienced in today's age of science and technology require having an effective science education system. Science education aims to gain the concept of science literacy. In addition to raising scientifically literate individuals, it also aims to provide basic life skills specific to the field of science, such as scientific process, engineering, and design skills. Science education enables individuals to acquire features that they can use in their daily lives such as model building, creativity, entrepreneurship, critical thinking, cooperation, problem solving, and product creation (Alaca, Yaman & Nas, 2020; Bakırcı & Kaplan, 2021; National Research Council [NRC], 2012). Individuals who are scientifically literate can interpret, explain, and evaluate this information by having an idea about scientific developments. They can take initiatives to understand the nature of scientific knowledge by approaching scientific discussions with a critical perspective (NRC, 2007). It can be claimed that the aim of raising individuals with 21st century skills can be achieved by an up-to-date science curriculum, well-trained science teachers, and the use of appropriate teaching methods and techniques. Therefore, individuals should benefit from technology in the process of accessing information, presenting, storing, and transferring information, and should be supported in terms of these features. Competencies such as learning to learn, digital, logical, and spatial thinking are the skills that students will need in the future in terms of their academic, personal, and social development (MoNE, 2018). In the science curriculum, it is aimed to enable individuals to reveal their creativity and be directly involved in the learning process by being aware of their responsibilities, which is in line with the 21st century skills (Akpınar & Ergin, 2005). Moreover, methods and techniques chosen are of great importance, especially in learning difficult or abstract concepts, increasing motivation, academic achievement, or interest in science (Hiğde & Aktamış, 2022; Kang & Keinonen, 2018; Önal & Önal, 2021) besides the skills of science teachers, who are directly involved in the learning process of individuals and responsible for providing better management of education.

* Corresponding Author: *Eylem Eroğlu*, *edogan@ibu.edu.tr*

The science courses are generally intertwined with the elements of daily life. More meaningful and permanent learning is provided when students interact with daily life and take an active role in learning by doing and experiencing. Thus, using techniques such as augmented reality (AR) and modeling on science subjects that remain abstract for students may contribute to meaningful and permanent learning. In most cases, individuals cannot visualize the information they need to learn in their minds. In such cases, there is great benefit in using models in education (Benzer & Ünal, 2021; Damerau et. al., 2022; Ke, Sadler, Zangori, & Friedrichsen, 2021; Sarıkaya, Selvi & Doğan Bora, 2004; Yiğit & Akdeniz, 2000). The use of models in education is of great importance in transferring and concretizing the course content to students. Models and modelling should be used while creating a scientific product (Minaslı, 2009). The use of models in the classroom allows students to develop their imaginations and scientific thinking skills while also creating mental models (Çoban, 2009). Science education is a very convenient branch in the use of models due to the subjects it contains and is an area where abstract concepts and events are intense. With regard to this aspect, it is known that students have difficulties in making sense of the course content (Ecevit & Özdemir Şimşek, 2017). Modeling techniques are of great importance for science education at the stage of knowledge creation (Koponen, 2007). Models developed for learning science lessons allow students to explain, define, and generalize scientific subjects. The models used in the course process enable students to visualize the existing model in their minds. Thanks to the models, the event or process to be conveyed is embodied and presented to the student (Gilbert & Boulter, 1998). When looking at the research in the literature, it's clear that individuals' interest in the lesson has increased (Schimmel, 2020) and their cognitive process skills have improved (Gilbert, 1990). Demirel and Altun (2007) stated in their studies that individuals can easily visualize the information they need to learn in their minds, and permanent learning emerges. In many studies, it is seen that significant changes occur in students' attitudes and motivations during the teaching process with models (Çevik, 2018; Özcan, 2016; Ulusoy, 2011; Ünal & Benzer, 2021; Zeytinli-Ünal, 2018). Among other studies, models improve mental skills by increasing academic achievement and increasing three-dimensional thinking (Akıllı, 2011; Akıllı & Seven, 2014; Canlas & Guevarra, 2020; Minaslı, 2009; Özcan, 2016; Vergara-Díaz, Bustamante, Pinto & Cofré, 2020). According to the research, students learn mental abilities such as problem solving, analyzing, and synthesizing because of the use of models in science classes (Günbatar & Sarı, 2005).

Augmented Reality technology enables real and virtual environments to come together to create an environment consisting of video, audio, or three-dimensional animations (Cheng & Tsai, 2013). When the history of this technology is examined, it was first employed in military, industrial, and medical investigations (de Souza Cardoso, Mariano & Zorzal, 2020; Eckert, Volmerg & Friedrich, 2019; Vaughan-Nichols, 2009). At present, it continues to be used in the educational process (Yen, Tsai & Wu, 2013). The most important reason behind the rapid spread and ease of accessibility of AR technology is that it has moved away from high-cost and complex equipment (Wu, Lee, Chang & Liang, 2013). Today, AR applications, which can be easily used in harmony with computers, tablets, and smart phones, can be used by every individual with these devices. The fact that the cost of this technology has become accessible with the development of technology has also positively affected its accessibility in educational environments. Textbooks have begun to be equipped with this technology. AR applications emerge as a technology that makes learning environments more fun and active for students instead of classical education-teaching environments (Birişçi & Karal, 2010; Önal & Önal, 2021). With the use of AR technologies in science education, course content is provided to be more meaningful and permanent. For example, laboratories are of great importance in learning science, but today, laboratory facilities are not available in every school. Even if a laboratory exists, its continuous use is impossible due to a lack of materials (Çallıca, Erol, Sezgin, & Kavcar, 2001; Güzel, 2000; Üce, Özkaya, & Şahin, 2001). The experiments, which must be observed in the laboratory, can be observed by the students with AR technology. Contrary to traditional methods and techniques, the use of technology in science education with AR applications is of great importance in schools where the laboratory environment is inaccessible (Özdener, 2005).

Augmented reality applications are becoming increasingly important in the process of integrating technology into education. With AR technology, opportunities such as video, sound and three-dimensional visuals have started to take place in education more frequently. In science education, it has become one of the elements that will enable students to embody the course content by making use of visual elements while telling a story. When the literature is examined, it has been shown that using AR applications in learning environments improves student success (Abdüsselam & Karal, 2012; Kalemkuş & Kalemkuş, 2022; Kan & Özmen, 2021; Kirikkaya & Basgül, 2019 Özarslan, 2013; Shelton & Hedley, 2002; Zhang, Sung, Hou & Chang, 2014). It is among the other studies that it has an effective role in increasing students' motivation and interest towards the lesson (Arici, Yildirim, Caliklar & Yilmaz, 2019; Delello, 2014; Kirikkaya & Basgül, 2019; Saadon, Ahmad, Pee & Hanapi, 2020). Chang, Chen & Huang (2011) stated in their study that AR applications contribute to effective learning by increasing students' motivation to participate in educational activities. Kececi and his colleagues (2021) found that mobile augmented reality (MAR) applications had a significant impact on academic achievement levels but did not play a determinant role in the development of the students' attitudes toward science and technology.

The review of the relevant literature indicates that using models as a tool, the modelling process as a method, and AR technology in science education is very important in that they will help students clarify abstract concepts or phenomena in their minds, increase their academic achievement, motivation, and interest in science. However, although various studies have been conducted in different areas of science education, there is only a recent study dealing with the effect of modelling and AR technology on a middle school science topic. In that study, Baba, Zorlu & Zorlu (2022) found that use of AR technology and modeling-based teaching in covering the "Solar System and Eclipses" unit of the science course has positively affected attitudes towards AR applications, academic success levels, and improved 21st-century skills. On the other hand, no study has been found in which the effects of modeling and AR applications are researched separately in the same study. Moreover, the "Support and Movement System" topic in the 6th grade science curriculum has not yet been researched in detail using modelling and AR technology applications. This topic is suitable to be investigated with modelling and AR technology applications. Consequently, the present study aims to fill this gap in the literature. It is also within the scope of the current study that teachers are involved in innovation by giving more space to technology, models, and competencies (learning to learn, digital competency, competencies in science and technology, etc.) in the teaching process, supporting the training of individuals who will gain 21st century skills. The main aim of the study is to investigate how models and materials created with AR technology on the topic of "Support and Movement Systems" in the "Systems in Our Body" unit of the 6th grade science lesson in middle school affect students' academic success as well as their interest and motivation towards the science lesson. In parallel with the purpose of the study, the following research questions and sub-questions will be answered:

The research question is, "Does the use of models and augmented reality technology in science education have an effect on the academic success, motivation, and interest levels of sixth grade middle school students?"

The sub-questions of the research are as follows:

- Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' pre-test scores?
- Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' post-test averages?
- Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' pre-test and post-test scores?

Method

This research was carried out under the quantitative research methodology with a pretest-posttest quasi-experimental design consisting of two experiments and one control group. The quasi-experimental design is often used in studies conducted in the field of education when all variables cannot be controlled (Cohen, Manion, & Marrison, 2000). The sampling method of the research is the variable that cannot be controlled due to the selection of the appropriate sample. The quasi-experimental design facilitates the discovery of the cause-effect relationship between the variables in the research (Büyüköztürk, 2016). The groups that will take part in the study in the quasi-experimental design are formed in advance by the researcher. Experimental and control groups are determined in accordance with the sample of the study. A quasi-experimental design was used since the participants were not selected randomly from the population in this study. According to the results of the statistical analysis of the comparison of the groups at the pre-test, there was no statistically significant difference between the groups. Before starting the research, comparing the groups in terms of pre-test results, and determining their equivalence plays an important role in increasing internal validity (Martella, Nelson, Morgan & Marchand-Martella, 2013). Accordingly, no matching was made between the control and experimental groups, a random selection was made, and the groups were formed.

Two different experimental groups are used in the study. The first experimental group (E1) was formed as an AR group, and the second experimental group (E2) was formed as a modeling group. The application was completed in 4 weeks, with 4 lesson hours per week. The students in the control group (C) performed the activities in the textbook in accordance with the present science curriculum. While students in the first experimental group used materials for AR applications, students in the second experimental group were required to model the skeletal system using modeling techniques.

Table 1. Experimental design of the study

Groups	Pre-test	Procedure	Post-test
Control (C)	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)	Use of Traditional method	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)
1st Experimental, E1 (Augmented Reality Group)	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)	Use of Augmented Reality Technology	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)
2nd Experimental, E2 (Modelling Group)	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)	Use of Modelling Technology	Science Motivation Scale (SMS) Science Interest Scale (SIS) Science Achievement Test (SAT)

Sample

The research sample consists of sixth-grade students enrolled in a public middle school in Istanbul's Küçükçekmece district during the first semester of the 2020-2021 academic year. 66 students who volunteered to participate in the study were chosen using a convenient sampling method, which is one of the non-random sampling methods. For the researcher, the convenient sampling method is based on accessibility and convenience. Convenient sampling is a method that aims to collect data quickly due to its easy access (Berg, 2001).

Data Collection Tools

Science Achievement Test (SAT), Science Motivation Scale (SMS) and Science Interest Scale (SIS) were used as data collection tools in the research.

Science Achievement Test: Developed by Ermiş (2012), SAT was applied as a pre-test at the beginning of the application and as a post-test at the end of the application to measure the pre-knowledge of the students in the control and experimental groups about the "Support and Movement" system and the learning difference that will occur in the students. SAT consists of 30 multiple-choice questions with 4 options. The mean difficulty index of the original test was 0.47, and the reliability coefficient KR-20 was determined as 0.568. The duration of the SAT is 40 minutes. The researchers applied the Science Achievement Test to a group of 60 students who did not participate in the study. The mean difficulty index and KR 20 value of SAT were calculated as 0.47 and 0.72, respectively.

Science Motivation Scale: Developed by Dede and Yaman (2008), SMS with 23 items on a 5-point Likert-scale was used as a pretest and posttest to assess students' motivation for learning science. The scale consists of "5=Strongly Agree, 4=Agree, 3=Undecided, 2=Disagree, 1=Strongly Disagree". The original reliability coefficient was determined as 0.82. The duration of the test is 20 minutes. In this study, the Cronbach alpha coefficient of SMS was found to be 0.80 by the researchers, which is very close to the original value.

Science Interest Scale: The Science Interest Scale developed by Şimşek and Nuhoğlu (2013) was used to determine the interest of the students in the science lesson. SIS is a 5-point Likert type consisting of "5 = Totally Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree". The scale consists of 27 items. The original reliability coefficient of the scale (Cronbach Alpha) was found to be $\alpha=0.79$. The reliability coefficient obtained shows that it is a highly reliable scale in the fields of education and social sciences. The application time for SIS is 20 minutes. The reliability coefficient of the scale was similarly calculated by the researchers as $\alpha=0.77$, which is again very close to the original value.

Analysis of Data

Because the data obtained were not perfectly consistent with the normal distribution (Table 2), and the number of participants in each group was less than 30 ($n<30$), non-parametric tests were chosen (Büyüköztürk, 2016). In the case of a comparison of two or more samples, each independent sample should be distributed normally (Orcan, 2020), which is not the case for the current study. The parametric tests shouldn't be utilized if any of the independent samples deviates from normality, which means if one of the groups is normally distributed and the others are non-normally distributed, the normality assumption is violated (Rietveld & van Hout, 2015). When comparing the SMS, SIS, and SAT pre-test and post-test scores of experimental and control groups, the Kruskal-Wallis test was used. The Mann Whitney U Test was employed as a "post hoc" test to determine which groups differed from the others after the Kruskal-Wallis test revealed a significant difference. A Wilcoxon Signed Ranks test was used when comparing the pre-test and post-test data in the third sub-problem.

Table 2. Normality test results of the study

Groups	Pre-Post tests	Shapiro-Wilk	df	p
Control (C)	SMS Pre-test	.880	22	.012
	SMS Post-test	.923	22	.088*
	SIS Pre-test	.918	22	.070*
	SIS Post-test	.976	22	.839*
	SAT Pre-test	.939	22	.187*
	SAT Post-test	.956	22	.409*
1st Experimental, E1	SMS Pre-test	.956	22	.418*
	SMS Post-test	.903	22	.034
	SIS Pre-test	.951	22	.324*
	SIS Post-test	.971	22	.739*
	SAT Pre-test	.956	22	.415*
	SAT Post-test	.850	22	.003
2nd Experimental, E2	SMS Pre-test	.967	22	.652*
	SMS Post-test	.876	22	.010
	SIS Pre-test	.959	22	.461*
	SIS Post-test	.917	22	.067*
	SAT Pre-test	.933	22	.139*
	SAT Post-test	.895	22	.024

*p>.05

Implementation Process

The control and experimental groups of the research consisted of 22 students each. The study consists of two experimental groups and one control group. The first experimental group is the AR experimental group, and the second experimental group is the modeling experimental group. The research implementation process was completed in a total of four weeks (16 course hours) out of four course hours per week. During data collection, SAT, SMS, and SIS were applied before and after the study in the AR experimental group, modeling experimental group, and control group. The process was carried out by the same researcher to ensure that different variables did not alter the application process. During the application process, a lesson plan for the skeletal system model and AR t-shirt was prepared in accordance with the materials to be utilized in the study. The related learning outcomes in the science curriculum that were incorporated into the lesson plan are given below.

"F.6.2.1.1. explains the structures of the support and movement system with examples."

a. Bone types are given as short, long, and flat without going into the structure of the bones.
b. Joint types are given without going into details.
c. The working principles of muscle types (voluntary and involuntary) and fatigue conditions are given within the framework of their detailed structures.

The students in the control group performed the activities in the textbook in accordance with the curriculum. While the students in the 1st experimental group used materials for AR technology, the students in the 2nd experimental group designed a model for the skeletal system with the modeling technique. All the scales determined as data collection instruments were delivered to the students in the study to collect pre-test and post-test data.

In the control group (C), before starting the application, SAT, SMS, and SIS were applied to the students to collect the pre-test data. The lecture was given to the control group by using direct lecture and question-answer technique during the application phase, and the students did the activities in the textbook. After explaining the subject area of "Support and Movement System," the post-test data for the control group were collected using the Science Achievement Test, Science Motivation Scale, and Science Interest Scale.

In the first experimental group (E1) in which the AR t-shirt was applied, before starting the application, SAT, SMS, and SIS were applied to the students to collect the pre-test data. The students in the first experimental group were told about the virtual reality application designed by the researcher with AR technology before the lecture process. In the design process of the mobile application designed with the name of AR t-shirt; Unity 3D Game Development Program (5.2.2), Vuforia SDK (software development kit) and “Android Studio” program for the Android Operating System were used. Our main goal has been to design an application that will attract the attention of students in the AR mobile application developed to convey the subject of “Support and Movement Systems” in the “Systems in Our Body” unit to 6th grade students. In the AR t-shirt application designed with the Unity 3D game development program, a skeletal system photograph was determined to be used as a marker by the researcher. Such a decision was made during the development process, considering that choosing a photograph suitable for the subject would attract the attention of the students more and arouse greater interest in the students compared to the applications made on the data matrix. The photograph, which was decided to be a maker (marker), was turned into a file with a sdk extension compatible with the Unity 3D game development program by making the necessary actions on the Vuforia website. After the marker was created, the photograph was matched with the relevant lecture video and a three-dimensional skeletal system image. There are buttons that allow students to go forward and backward while using the application. While creating the buttons, they were written using the "C#" coding language. With the inclusion of the buttons in the application, it was easier for the students to reach the image they wanted between the video with the lecture and the 3D visual. After the design phase of the application, the material on which the marker will be printed was chosen as a t-shirt. The fact that the material was preferred as a t-shirt instead of a normal piece of paper contributed to the emergence of an educational material designed with wearable technology. In this aspect, it differs from other AR applications used in education. After the design process was completed, it was made compatible with mobile devices using the Android Studio platform. The application will be ready for students to use within a month. During the lecture process, all students were dressed in AR t-shirts to observe with their peers. The mobile AR application was installed on the mobile devices of the students, and they were enabled to use the application. They had the opportunity to observe the 3D skeleton system and the videos with lectures in the application via the camera of any mobile device with the Android operating system on the t-shirt. After the application, which was met with interest by the students, SAT, SMS, and SIS were applied to the students again at the specified times as a post-test.

In the 2nd experimental group (E2) in which the modeling technique was applied, SAT, SMS, and SIS were applied to the students to collect the pre-test data, and then the students were informed about the modeling teaching technique. At the beginning of the lesson, questions were asked by the researcher to measure the students' prior knowledge. The instructions for the skeletal system model to be made during the lesson were explained to the students by the teacher. By using the modeling technique, the students were able to design their own materials during the lesson and to be actively involved in the educational teaching process. At the end of the application process, which the students were very interested in, SAT, SMS, and SIS were applied to the students again at the specified times as a post-test.

Results

In this part of the research, a pre-test was conducted to investigate the effects of using models and materials designed with AR application about support and movement systems in the "Systems in Our Body" unit of a middle school 6th grade science lesson on the academic success of students, their interest and motivation towards the science lesson. The findings were obtained from the Science Motivation Scale (SMS), Science Interest Scale (SIS), and Science Achievement Test (SAT), which were applied as a post-test.

Findings Concerning the First Sub-Question of the Study

To find an answer to the first sub-question, namely “Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' pre-test scores?” In the research, the Kruskal-Wallis test was performed on the collected pre-test data and the results are given in Table 3.

According to the findings in Table 3, the Science Motivation Scale (SMS), Science Interest Scale (SIS) and Science Achievement Test (SAT) pre-test scores of the students participating in the research were higher than $p>0.05$ ($p=0.124$, $p=0.842$, $p=0.815$), it is seen that the pre-test results did not differ significantly. These results show that the individuals who will be included in the research are equivalent in terms of science achievement, motivation, and interest levels.

Table 3. Analysis results of SMS, SIS and SAT pre-tests scores of experimental and control groups

Pre-tests	Groups	N	Mean Rank	Kruskal Wallis	Sd	p
Science Motivation Scale (SMS)	1st Experimental, E1	22	33,55	4,178	2	0,124
	2nd Experimental, E2	22	27,59			
	Control (C)	22	39,36			
Science Interest Scale (SIS)	1st Experimental, E1	22	33,20	0,343	2	0,842
	2nd Experimental, E2	22	31,98			
	Control (C)	22	35,32			
Science Achievement Test (SAT)	1st Experimental, E1	22	34,09	0,409	2	0,815
	2nd Experimental, E2	22	31,43			
	Control (C)	22	34,98			

*p<0.05

Findings Concerning the Second Sub-Question of the Study

To find an answer to the second sub-question, namely "Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' post-test averages?" In the research, the Kruskal-Wallis test was performed on the collected post-test data and the results are given in Table 4.

Table 4. Kruskal Wallis test results of SMS, SIS and SAT post-tests scores of experimental and control groups

Post-tests	Groups	N	Mean Rank	Kruskal Wallis	Sd	p
Science Motivation Scale (SMS)	1st Experimental, E1	22	47,50	44,476	2	0,000*
	2nd Experimental, E2	22	41,50			
	Control (C)	22	11,50			
Science Interest Scale (SIS)	1st Experimental, E1	22	47,64	44,560	2	0,000*
	2nd Experimental, E2	22	41,36			
	Control (C)	22	11,50			
Science Achievement Test (SAT)	1st Experimental, E1	22	38,91	14,831	2	0,001*
	2nd Experimental, E2	22	40,86			
	Control (C)	22	20,73			

*p<0.05

When we examine the findings in Table 4, it is seen that the AR, modeling, and control groups met the $p<0.05$ value in terms of Science Motivation Scale, Science Interest Scale, and Science Achievement Test post-test scores ($p=0.000$, $p=0.000$, $p=0.001$) and this shows the result that there is a statistically significant difference. A Mann-Whitney U test was used to determine between which groups this significant difference was found.
The results of the test are presented in Tables 5, 6, and 7.

Table 5. Mann Whitney U test results of SMS post-test scores of experimental and control groups

Post-test	Groups	N	Mean Rank	Sum of Rank	U	p
Science Motivation Scale (SMS)	1st Experimental, E1	22	22,50	561,0	176,0	0,121
	2nd Experimental, E2	22	19,50	429,0		
	1st Experimental, E1	22	33,50	737,0	0,000	0,000*
	Control (C)	22	11,50	253,0		
	2nd Experimental, E2	22	33,50	737,0	0,000	0,000*
	Control (C)	22	11,50	253,0		

*p<0.05

Considering the statistical value of $p<0.05$ ($p=0.000$), it is seen that there is a significant difference between the test results between the students studying with AR in Table 5 and the students who are in the control group and take courses according to the Science curriculum. When we examine the results of the modeling experimental group and the control group, it is seen that there is a significant difference in terms of $p<0.05$ ($p=0.000$) statistical value. When we examine the test results of AR and modeling technique, it is seen that there is no significant difference between the two experimental groups in terms of p>0.05 (p=0.121). According to these results, compared to the control group, the groups taught with AR and modeling techniques have a similar effect on students' motivation towards the science lesson.

Table 6. Mann Whitney U test results of SIS post-test scores of experimental and control groups

Post-test	Groups	N	Mean Rank	Sum of Rank	U	p
Science Interest Scale (SIS)	1st Experimental, E1	22	25,64	564,0	173,0	0,105
	2nd Experimental, E2	22	19,36	426,0		
	1st Experimental, E1	22	33,50	737,0	0,000	0,000*
	Control (C)	22	11,50	253,0		
	2nd Experimental, E2	22	33,50	737,0	0,000	0,000*
	Control (C)	22	11,50	253,0		

*p<0.05

When we examine the findings in Table 6, it is concluded that there is no statistically significant difference p>0.05 (p=0.105) between AR and modeling techniques in terms of Science Interest Scale. This finding shows that the AR and modeling groups affect the interest in science at a similar level in terms of teaching technique. When we continued to analyze the results of the FBI Post-test, a statistically significant difference was found p<0.05 (p=0.000) in the test results applied to the students in the AR and control group and the students in the Modeling and control group. The results of this analysis show that AR and modeling techniques are effective in increasing students' interest in science.

Table 7. Mann Whitney U test results of SAT post-test scores of experimental and control groups

Post-test	Groups	N	Mean Rank	Sum of Rank	U	p
Science Achievement Test (SAT)	1st Experimental,	22	21,66	476,50	223,5	0,662
	2nd Experimental,	22	23,34	513,50		
	1st Experimental,	22	28,75	632,50	104,5	0,001*
	Control (C)	22	16,25	357,50		
	2nd Experimental,	22	29,02	638,50	98,50	0,001*
	Control (C)	22	15,98	351,50		

*p<0.05

When we examine the findings in Table 7, it is seen that there is no statistically significant difference between AR and modeling technique in terms of Science Achievement Test, p>0.05 (0.662). When the Science Achievement Test results of the students in the control group and the AR and modeling groups are compared, it is seen that there is a statistically significant difference, p<0.05 (p=0.001). Students in the AR group and modelling group students scored statistically higher than the students in the control group in the Science Achievement Test.

Findings Regarding the Third Sub-Question of the Study

The third sub-question of the research was namely as follows: "Is there a statistically significant difference in academic achievement, motivation, and interest in science between the experimental and control group students' pre-test and post-test scores?" To find an answer to this sub-question, the pretest-posttest data collected was subjected to the Wilcoxon Signed Ranks test. The findings obtained are presented in the tables below.

When the data in Table 8 are examined, a statistically significant difference (P = 0.000) is found between the SMS pre-test and post-test results of the AR (E1) and modeling (E2) groups. In the control group, in which the SMS test was applied, there was no statistically significant difference (p = 0.066) between the pre-test and post-test results. This situation shows that teaching with a traditional approach does not affect students' motivation towards science courses. On the other hand, it was revealed that AR and modeling positively affected students' motivation towards science lessons.

Table 8. Wilcoxon Signed Ranks test results of SMS pretest-posttest scores of experimental and control groups

Groups	Ranks	N	Mean Rank	Sum of Ranks	Z	p
1st Experimental, E1	Negative	0	0,00	0,00		
	Positive	22	11,50	253,00	-4,108	0,000*
	Ties	0				
	Total	22				
2nd Experimental, E2	Negative	0	0,00	0,00		
	Positive	22	11,50	253,00	-4,109	0,000*
	Ties	0				
	Total	22				
Control, C	Negative	0	0,00	0,00		
	Positive	4	2,50	10,00	-1,841	0,066
	Ties	18				
	Total	22				

*p<0.05 *p<0.05 *p<0.05 *p<0.05 *p<0.05

Table 9. Wilcoxon Signed Ranks test results of SIS pretest-posttest scores of experimental and control groups

Groups	Ranks	N	Mean Rank	Sum of Ranks	Z	p
1st Experimental, E1	Negative	0	0,00	0,00		
	Positive	22	11,50	253,00	-4,109	0,000*
	Ties	0				
	Total	22				
2nd Experimental, E2	Negative	0	0,00	0,00		
	Positive	22	11,50	253,00	-4,111	0,000*
	Ties	0				
	Total	22				
Control, C	Negative	0	0,00	0,00		
	Positive	14	7,50	105,00	-3,320	0,001*
	Ties	8				
	Total	22				

* p<0.05

When the findings in Table 9 were examined, it was found that there was a statistically significant difference at the level of $p<0.05$ ($p=0.000$ and $p=0.001$) between the Science Interest Scale pre-test and post-test scores of the AR, modeling, and control group students. The fact that the sums of positive order differences in the groups ($\Sigma S+ = 253.0$, $\Sigma S+ =253.00$ and $\Sigma S+ = 105.0$) in the groups are larger than the negative order difference sums ($\Sigma S-=0.00$), the applied teaching techniques reveal that they are effective in increasing students' interest in science.

Table 10. Wilcoxon Signed Ranks test results of SAT pretest-posttest scores of experimental and control groups

Groups	Ranks	N	Mean Rank	Sum of Ranks	Z	p
1st Experimental, E1	Negative	0	0,00	0,00		
	Positive	22	11,50	253,00	-4,116	0,000*
	Ties	0				
	Total	22				
2nd Experimental, E2	Negative	4	5,88	23,50		
	Positive	18	12,75	229,50	-3,347	0,001*
	Ties	0				
	Total	22				
Control, C	Negative	1	3,00	3,00		
	Positive	8	5,25	42,00	-2,373	0,018*
	Ties	13				
	Total	22				

*p<0.05

When the results obtained are examined, it is seen that the AR, modeling, and control group students' Science Achievement Test, pre-test and post-test, scores were statistically significant; $p<0.05$ ($p=0.000$, $p=0.001$ and $p=0.018$). At the statistical level, it was concluded that there was a significant difference. Furthermore, the fact that the sums of positive order differences ($\Sigma S+ = 253.0$, $\Sigma S+ =229.00$) in the groups are greater than the sums of negative order differences (ΣS-=0.00 and ΣS-=23.50) in the groups, reveals that individuals are effective in increasing their success in science.

Discussion

In this study, the effect of using models and AR applications on students' academic achievement, motivation, and interest levels was examined. In the study, the Science Achievement Test was used to measure academic achievement, and the Science Motivation and Science Interest Scales were used to measure interest and motivation towards science. The study's data were statistically analyzed, and the results were discussed in order to answer the research question.

The first sub-problem of the study, "Is there a significant difference between the pre-test scores of the experimental group and control group students in terms of academic achievement, motivation towards science lessons, and interest towards science lessons?" When the findings obtained to answer the question were examined, it was found that there was no significant difference between the pre-test results of the students who were studying with AR, modeling, and traditional learning methods (Table 3). This finding shows that the experimental groups and control groups formed within the scope of the research are equivalent in terms of science achievement, motivation, and interest levels.

The second sub-problem of the study is, "Is there a significant difference between the post-test averages of the experimental groups and the control group students in terms of academic achievement, motivation towards science lessons, and interest towards science lesson?" The Kruskal-Wallis and Mann-Whitney U tests were applied to the data obtained to find an answer to the question. Analysis results have shown that there is a statistically significant difference between the Science Motivation Scale, Science Interest Scale, and Science Achievement Test post-test scores of the AR experimental group, the modeling experimental group, and the control group students studying with the traditional approach (Table 4). Mann-Whitney U tests were performed to determine between which groups this significant difference was found. Test results showed that there was a statistically significant difference at the $p<0.05$ level between the AR experimental group and the control group in favor of the AR group and between the modeling experimental group and the control group in favor of the modeling group in terms of motivation, interest, and achievement scores towards science (Table 5, 6, and 7). On the other hand, no statistically significant difference was determined between the AR and modeling experimental groups in terms of motivation, interest, and achievement post-test scores. These findings reveal that the AR application and modeling techniques are effective in increasing students' academic success and their interest and motivation towards science compared to the control group, but there is no significant difference between the two techniques in terms of positively affecting the test results. It has not been possible to compare our results with the relevant literature because there is no study in the available literature investigating the effects of AR and modeling techniques separately on learning middle school science topics. However, in a very recent study, Baba, Zorlu & Zorlu (2022) used a similar pretest-posttest quasi-experimental design, consisting of one experimental and one control group to examine the effects of AR and modeling techniques on the "Solar System and Eclipses" unit. Since they have formed the experimental group in a way to investigate the effects of both techniques together, it cannot be said that the design they used is fully compatible with our experimental design. Nevertheless, the research results they have found are similar to our results in terms of increasing academic achievement.

The third sub-problem of the research, "Is there a significant difference between the pre-test and post-test scores of the experimental groups and control group students in terms of their academic achievement, motivation towards science lessons, and interest towards science lessons?" The data collected to answer the question was analyzed with the Wilcoxon Signed Ranks test. Analysis results showed that there was a statistically significant difference at $p<0.05$ level between motivation, interest, and achievement pretest scores and posttest scores of the AR and modeling groups (Tables 8, 9 and 10). There was no statistically significant difference between the pre-test and post-test scores of the control group in which the traditional teaching method was applied. These findings obtained from within-group comparisons show parallelism with the findings of intergroup comparisons carried out within the scope of the second sub-problem. As a result, both intra-group pretest-posttest scores and intergroup posttest score comparisons reveal that AR and modeling techniques positively affect students' academic achievement, interest, and motivation towards science. This situation can be interpreted as the use of AR and modeling activities in the lessons leads to the concentration of the students' attention, thus increasing their interest, motivation, and success in the lesson. In many studies similar to ours in different age groups and different subjects in the literature, it has been determined that the use of models in the education-teaching process leads to an increase in the academic success of individuals and the acquisition of many different skills (Akıllı, 2011; Balkan, 2007; Batı, 2014; Bilal, 2010; Burkaz, 2012; Çoban, 2009; Demirçalı, 2016; Harrison, 2001; Köklü, 2009; Minaslı, 2009; Örnek, 2010; Özcan, 2016; Zeynelgiller, 2006; Zeytinli-Ünal, 2018). Demirel and Altun (2007) stated that the use of models in education provides permanent learning by better understanding the course contents by the students. Teaching science with models contributes to the development of individuals' mental process skills such as analysis, synthesis, evaluation, and problem solving (Günbatar & Sarı, 2005). In science lessons, the teaching methods and techniques that should be used while teaching students are of great importance. The more the course's methods and techniques appeal to the student's sensory organs, the more successful the student will be in the course. The findings we obtained as a result of using the models that can be used in 3D in the course are compatible with the findings of similar studies (Akıllı, 2011; Akıllı & Seven, 2014; Minaslı, 2009; Özcan, 2016). In these studies, it was concluded that the use of three-dimensional models contributed to the development of students' three-dimensional thinking skills by increasing academic success in the course. In another study, Akıllı and Seven (2011) made use of this technology while explaining the structure of the atom to students and concluded that it increased students' academic success. Harrison and Treagust (1998), on the other hand, stated that the use of multiple models in science lessons increased the effectiveness of the education. The use of modeling teaching techniques increases the permanence of the information learned by the students by taking an active role in the course process. Some studies revealing the effect of modeling on students' academic success in science courses support our research results (Çökelez, 2015; Düşkün, 2011; Gümüş, Demir, Koçak, Kaya & Kırıcı, 2008).

In studies where AR technology is used, results have been obtained that individuals using this technology are very satisfied with using this technology and would like to use it again (Abdüsselam & Karal 2012; Kırıkkaya & Şentürk 2018; Özarslan, 2013; Sırakaya, 2015). Küçük (2015) stated that the use of this technology in lessons leads to many positive results, such as creating a sense of reality in students, concretizing abstract elements, and increasing the student's interest, curiosity, and success in the lesson. Similar to the results we have obtained, studies have been found in the literature showing that AR technology is effective in attracting students' attention and increasing their interest and motivation towards the lesson (Arici, Yildirim, Caliklar & Yilmaz, 2019; Kirikkaya & Basgül, 2019; Küçük, 2015; Saadon, Ahmad, Pee & Hanapi, 2020; Tomi & Rambli, 2013). In addition, in parallel with the findings we have obtained in some studies (Kalemkuş & Kalemkuş, 2022; Kan & Özmen, 2021; Kırıkkaya & Şentürk 2018; Kirikkaya & Basgül, 2019; Şahin, 2017), it has been stated that AR technology has a positive effect on student achievement in lessons. In a study conducted by Akçayır and Akçayır (2017), it was determined that the use of AR applications in the education-teaching process met their interest and led to an increase in their academic success since individuals are willing to use mobile devices. In a different study, it was concluded that if AR mobile applications are used in the lessons, the motivation and success of the individuals towards the lesson increase (Erbaş, 2016).

The use of the AR t-shirt in the lesson positively affected the motivation of the students. Students encountered wearable technology for the first time. As a result of the research data, it was seen that the students in the experimental group who used AR material had higher motivation compared to the control group because the application used was fun. The advantages provided to students by the AR application enabled them to have high motivation (Delello, 2014; Özarslan, 2013; Taşkıran, Koral & Bozkurt, 2015; Tian, Endo, Urata, Mouri & Yasuda, 2014). The effect of the AR material on the academic achievement of the students is that they are more successful than the students in the control group. Many academic studies in the literature support the conclusion reached (Abdüsselam & Karal, 2012; Fleck, Simon & Christian Bastien, 2014; Önal & Önal, 2021). As a result of research data, the use of AR and modeling techniques in science education has a positive effect on students' academic achievement and motivation, as well as increases students' interest and attention. Studies that are compatible with the results we obtained are found in the literature (Delello, 2014; İbili & Şahin, 2013; Saadon, Ahmad, Pee, & Hanapi, 2020). The AR and modeling techniques and the materials used in the course process increased the interest of the students towards the science course. With the modeling and AR applications, students took an active role in the course process and their academic achievements improved positively (Baba, Zorlu & Zorlu, 2022; Delello, 2014).

Conclusion and Recommendations

The teaching methods and techniques used in the science course are of great importance in increasing the success of this course. In cases where the achievements in the science education program are abstract, they should be embodied in the minds of the students. In the case of using teaching methods and techniques that will facilitate students' understanding of abstract concepts in this way, it will be easier for individuals to make gains in behavior. Today, with developing technology, the integration of education and technology has gained great importance. Along with the models we use in the classroom, materials such as technological mobile applications and AR applications have begun to support the educational environment in the classroom. Models and AR applications are of great importance for individuals to make sense of abstract concepts. Participation of students in the lesson is a very effective technique in increasing their interest and motivation in the lesson. When it is desired to simulate how an event happened, models or AR applications can be used.

Students are of the opinion that there are not enough models for the abstract and difficult-to-understand subjects in the textbooks. Activities for AR applications in the textbooks of the Ministry of National Education have begun to take their place in today's books. With the use of students with tablets, technology has become accessible in every part of our country, from east to west. We need to emphasize the importance of developing technological materials in these days when we are fully involved in the integration of education and technology. Based on our data results, we can say that students' interest and motivation towards science increased with the AR t-shirt we designed during the process of carrying out the study. In addition to AR applications, among the other results that we have obtained, modeling increases the interest, motivation, and success of students.

With the use of modeling and AR applications in education, the development of behaviors such as problem solving, analysis, synthesis, and evaluation is provided in individuals. It is of great importance for students to benefit from models and technology in the education process, in the subjects they have difficulty in, in terms of their interest, motivation, and success in the course. While students benefit from modeling, they take an active part in the process, facilitating permanent and effective learning. With the correct use of models and AR applications in educational environments, as in the findings we obtained in our research, it is concluded that students' interest, motivation, and success in science lessons increase.

Some recommendations made in line with the findings obtained from the study are presented below.
• Models and AR applications were separately employed to teach the "Support and Movement System" topic in the 6th grade science curriculum. In each case, students' success, interest, and motivation in science were enhanced. The effect of using models and AR techniques to teach other topics in the science curriculum may also be beneficial to research.
• The study was carried out with 6th grade students. Similar studies can be carried out with students in different grades.
• The study was carried out using a quantitative research methodology with a pretest-posttest quasi-experimental design. A qualitative part can also be added for further research. Thus, students' opinions and views on the modelling and AR application processes can be explored in depth.
• Since the application of these techniques is found to be successful in increasing students' success, interest, and motivation in science, primary science teachers can be encouraged and trained to develop their own AR and modeling materials.
• This study is limited by the fact that only a small number of participants were involved. In order to increase the generalizability, the study can be repeated with a larger sample.

Acknowledgments or Notes

This study is produced from the master's thesis prepared by the first author under the supervision of the second author.

Author (s) Contribution Rate

The authors contributed equally to the article.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Ethical Approval

Ethical permission (Protokol No. 2019/313) was obtained from Bolu Abant İzzet Baysal University Social and Human Sciences Scientific Research and Publication Ethics Committee, for this research.

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. (2017). Advantages and challenges associated with augmented reality for education: a systematic review of the literature. *Educational Research Review*, *20*, 1–11.

Akıllı, M. & Seven, S. (2014). The effects of 3D computer models to academic achievement and spatial ability: atomic models. *Turkish Journal of Education, 3(*1), 11-23.

Akıllı, M. (2011). *The teaching of "structure of atom" subject to 2nd year primary science education students using 3D computer model* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 301121)

Akpınar, E. & Ergin, Ö. (2005). A sample instruction for science teaching based on constructivist theory. *Hacettepe University Journal of Education, 29*: 9-17.

Alaca, M. B., Yaman, H., & Nas, S. E. (2020). Using the word association test to examine life skills cognitive structures of pre-service science teachers. *Journal of Science Learning*, *4*(1), 69-79.

Arici, F., Yildirim, P., Caliklar, Ş., & Yilmaz, R. M. (2019). Research trends in the use of augmented reality in science education: Content and bibliometric mapping analysis. *Computers & Education*, *142*, 103647.

Baba, A., Zorlu, Y. & Zorlu, F. (2022). Investigation of the effectiveness of augmented reality and modeling-based teaching in "Solar System and Eclipses" unit. *International. Journal of Contemporary Educational Research*, *9*(2), 283-298.

Bakırcı, H., & Kaplan, Y. (2021). Encountered problems by science teachers in the field of engineering and design skills and suggestions for solutions. *Journal of Computer and Education Research Year*, *9*(18), 626-654.

Balkan, A. (2007). *The effects of using maps on lesson behaviors, achievement, and memorization level in social studies to the seventh-grade primary students* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 239072)

Batı, K. (2014*). The effectiveness of modeling-based science education; ıt's effects on students' views about nature of science and critical thinking* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 383791)

Benzer, A. I., & Ünal, S. (2021). Models and modelling in science education in turkey: A Literature review. *Journal of Baltic Science Education*, *20*(3), 344-359.

Berg, B.L. (2001). *Qualitative research, message for the social sciences* (4th Edition). Allyn and Bacon.

Bilal, E. (2010). *Effects of electricity instruction by modeling on conceptual understanding, academic achievement, and epistemological beliefs* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 265534)

Birişçi, S. & Karal, H. (2010). Pre-service computer teachers' views on usability of computer animations in education. *e-Journal of New World Sciences Academy*, *5*(4), 1614-1627.

Burkaz, S. (2012). *Application of three-dimensional modelling in the context of constructivist learning in teaching science and technology* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 317806)

Büyüköztürk, Ş. (2016). *Sosyal bilimler için veri analizi el kitabı* (22. Baskı). Pegem.

Çallıca, H., Erol, M., Sezgin, G. & Kavcar, N. (2001). *İlköğretim kurumlarında laboratuvar uygulamalarına ilişkin bir çalışma*. IV. Fen Bilimleri Eğitimi Kongresi, 217-219. Ankara: Hacettepe Üniversitesi Eğitim Fakültesi.

Canlas, A. C., & Guevarra, M. D. (2020). Model-based learning approach: effects on students' academic performance and attitudes in earth science. *Jurnal Pendidikan MIPA*, *21*(1), 49-66.

Çevik, M. E. (2018). *The effects of using models in the teaching of 11th grade gas unit on studens' achievement and their attitudes toward chemistry* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 517881)

Chang, Y. J., Chen, S. F. & Huang, J. D. (2011). A kinect-based system for physical rehabilitation: a pilot study for young adults with motor disabilities. *Research in Developmental Disabilities, 32*(6), 2566-2570.

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*(4), 449-462.

Çoban, G. Ü. (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* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 231558)

Cohen, L., Manion, L. & Morrison, K. (2000). *Research methods in education*. (5th Edition). London: Routledge Falmer. http://dx.doi.org/10.4324/9780203224342

Çökelez, A. (2015). Models and modeling in science education, teachers, prospective teacahers and students: literature review. *Literature and History of Turkish or Turkic, 10(*15), 255-272.

Damerau, K., Beudels, M. M., Börtitz, C., El Balti, N., Funk, L., Westerholt, D., Cohnen, J., & Preisfeld, A. (2022). The effect of teaching with anatomical models in science education on primary school children's understanding of human organs. *International Electronic Journal of Elementary Education*, *14*(4), 539–555.

De Souza Cardoso, L. F., Mariano, F. C. M. Q., & Zorzal, E. R. (2020). A survey of industrial augmented reality. *Computers & Industrial Engineering*, *139*, 106159.

Dede, Y. & Yaman, S. (2008). A questionnaire for motivation toward science learning: A validity and reliability study. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 1*(2), 19-37.

Delello, J. A. (2014). Insights from pre-service teachers using science-based augmented reality. *Journal of Computers in Education, 1*(4), 295–311. DOI:10.1007/s40692-014-0021-y

Demirçalı, S. (2016). *The effects of model-based science education on students' academic achievement, scientific process skills and mental model development: The sample of 7th grade unit of "The Solar System and Beyond: The Puzzle of Space"* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 450167)

Demirel, Ö. & Altun, E. (2007). *Öğretim teknolojileri ve materyal tasarımı* (1. Baskı). Pegem.

Düşkün, İ. (2011). *Sun-earth-moon model development and the effect on academic success in astronomy education of pre-service science teachers* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 286859)

Ecevit, T. & Özdemir Şimşek, P. (2017). The evaluation of teachers' science concept teaching and their action to diagnose and eliminate misconceptions. *Elementary Education Online, 16(*1), 129-150.

Eckert, M., Volmerg, J. S., & Friedrich, C. M. (2019). Augmented reality in medicine: systematic and bibliographic review. *JMIR mHealth and uHealth*, *7*(4), e10967.

Erbaş, Ç. (2016). *The effects of mobile augmented reality applications on students' academic achievement and motivation* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 426260)

Ermiş, U. (2012). *The effect of using smart board upon academic success and student motivation in science and technology lesson* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 317105)

Fleck, S., Simon, G. & Christian Bastien, J. M. (2014, September). AIBLE: *An inquiry-based augmented reality environment for teaching astronomical phenomena*. IEEE International Symposium on Mixed and Augmented Reality-Media, Arts, Social Science, Humanities and Design. Münich, Germany.

Gilbert, J. K. & Boulter, C. B. (1998). Learning science through models and modeling. In B. Fraser and K. Tobin. (Eds.), *International Handbook of Science Education* (pp.53-66). Kluwer Academic Publishers.

Gilbert. C. (1990), *Models for primary science and technology education*. Longman Group Resources Unit.

Gümüş, İ., Demir, Y., Koçak, E., Kaya, Y., & Kırıcı, M. (2008). The effects of model-teaching on students' success. *Erzincan University Journal of Education Faculty,* 65-90.

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

Güzel, H. (2000). *İlköğretim okullarında I. ve II. kademedeki fen bilgisi derslerinde laboratuvar etkinlikleri ve araç kullanımı düzeyi*. IV. Fen Eğitimi Kongresi. Ankara: Hacettepe Üniversitesi Eğitim Fakültesi.

Harrison, A. G. & Treagust, D. F. (1998). Modelling in science lessons: Are there better ways to learn with models. *School Science and Mathematics, 98*(8), 420-429.

Harrison, A. G. (2001). How do teachers and textbook writers' model scientific ideas for students? *Research in Science Education, 31*, 401-435.

Hiğde, E., & Aktamış, H. (2022). The effects of STEM activities on students' STEM career interests, motivation, science process skills, science achievement and views. *Thinking Skills and Creativity*, *43*, 101000.

İbili, E. & Şahin, S. (2013). Software design and development of an interactive 3D geometry book using augmented reality: ARGE3D. *Afyon Kocatepe University Journal of Science and Engineering, 13* (1), 1-8. DOI: 10.5578/fmbd.6213

Kalemkuş, J., & Kalemkuş, F. (2022). Effect of the use of augmented reality applications on academic achievement of student in science education: meta analysis review. *Interactive Learning Environments*, 1-18.

Kan, A. Ü., & Özmen, E. (2021). The effect of using augmented reality based teaching material on students' academic success and opinions. *African Educational Research Journal*, *9*(1), 273-289.

Kang, J., & Keinonen, T. (2018). The effect of student-centered approaches on students' interest and achievement in science: Relevant topic-based, open and guided inquiry-based, and discussion-based approaches. *Research in Science Education*, *48*(4), 865-885.

Ke, L., Sadler, T. D., Zangori, L., & Friedrichsen, P. J. (2021). Developing and using multiple models to promote scientific literacy in the context of socio-scientific issues. *Science & Education*, *30*(3), 589-607.

Kececi, G., Yildirim, P., & Zengin, F. K. (2021). Determining the effect of science teaching using mobile augmented reality application on the secondary school students' attitudes of toward science and technology and academic achievement. *Science Education International*, *32*(2), 137-148.

Kırıkkaya, B. E. & 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), 181-189.

Kirikkaya, E., & Basgül, M. S. (2019). The effect of the use of augmented reality applications on the academic success and motivation of 7th grade students. *Journal of Baltic Science Education*, *18*(3), 362-378.

Köklü, N. (2009). *The effect of pedagogic and analogic models in teaching of electrics subject to the success of student* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 237379)

Koponen, I.T. (2007). Models and modeling in physics education: a critical re-analysis of philosophical underpinnings and suggestions for revisions. *Science Education, 16*,751–753.

Küçük, S. (2015). *Effects of learning anatomy via mobile augmented reality on medical students' academic achievement, cognitive load, and views toward implementation* [Doctoral dissertation]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 389140)

Martella, R. C., Nelson, J. R., Morgan, R. L. & Marchand-Martella, N. E. (2013). *Understanding and interpreting educational research*, Guilford Press.

Minaslı, E. (2009). *The effect of using model and simulation teaching techniques on the achivement, concept learning and remembering in the unit of structure and properties of matter* [Master's thesis]. Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 250817)

MoNE (Ministry of National Education) (2018). *Fen bilimleri dersi öğretim programı (İlkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar) [Science course curriculum (primary and secondary school 3, 4, 5, 6, 7 and 8th Grades)]*. Ankara.

NRC. (2007). *Taking science to school: learning and teaching science in grades K-8*. National Academy Press. http://www.nap.edu/catalog/11625.html

NRC. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century. Committee on Defining Deeper Learning and 21st Century Skills*. Washington, DC: The National Academies Press. https://doi.org/10.17226/13398.

Önal, N. T., & Önal, N. (2021). The effect of augmented reality on the astronomy achievement and interest level of gifted students. *Education and Information Technologies*, *26*(4), 4573-4599.

Orcan, F. (2020). Parametric or non-parametric: skewness to test normality for mean comparison. *International Journal of Assessment Tools in Education*, *7*(2), 255-265. DOI: 10.21449/ijate.656077

Örnek, G. (2010). *The effects of the models on learning the subject `? mitosis division?? instructed in biology lessons at 10th grades of high schools* (Master's thesis). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 264327)

Özarslan, Y. (2013). *The effect of augmented reality enhanced learning materials on learners' achievement and learners' satisfaction* (Doctoral dissertation). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 331054)

Özcan, K. V. (2016). *The effects of 3D model assisted medical education on students' academic achievement, spatial skills, and attitudes* (Doctoral dissertation). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 433814)

Özdener, N. (2005). Deneysel öğretim yöntemlerinde benzetişim (simulation) kullanımı. *The Turkish Online Journal of Educational Technology, 4*(4), 13-19.

Rietveld, T. & van Hout, R. (2015). The t test and beyond: Recommendations for testing the central tendencies of two independent samples in research on speech, language and hearing pathology. *Journal of Communication Disorders*, (58), 158-168.

Saadon, N. F. S. M., Ahmad, I., Pee, A. N. C., & Hanapi, C. (2020, May). The implementation of augmented reality in increasing student motivation: systematic literature review. In IOP Conference Series: Materials Science and Engineering (Vol. 854, No. 1, p. 012043). IOP Publishing.

Şahin, D. (2017). *Effect of science teaching with the augmented reality technology on secondary school students' achievement and their attitude towards the course* (Master's thesis). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 459513)

Sarıkaya, R., Selvi, M. & Doğan Bora, N. (2004). Mitoz ve mayoz bölünme konularının öğretiminde model kullanmanın önemi. *Kastamonu Eğitim Dergisi*, *12*(1), 85-88.

Schimmel, J. (2020). Making the connection: Model-based learning in primary education (Master's thesis), Education: Science education and communication Organization: Utrecht University.

Shelton, B. E. & Hedley, N. R. (2002). *Using augmented reality for teaching earth-sun relationships to undergraduate geography students*. In Augmented Reality Toolkit, The First IEEE International Workshop. DOI: 10.1109/ART.2002.1106948

Şimşek, C. & Nuhoğlu, H. (2013). The development of a reliable and valid cruosityscale for science subjects. *Sakarya University Journal of Education Faculty, 0*(18), 28-41.

Sırakaya, M. (2015) *Effects of augmented reality applications on students' achievement, misconceptions, and course engagement* (Doctoral dissertation). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 419423)

Taşkıran, A., Koral, E. & Bozkurt, A. (2015). *Artırılmış gerçeklik uygulamasının yabancı dil eğitiminde kullanılması*. 15. Akademik Bilişim Kongresi. Eskişehir: Anadolu Üniversitesi. 4-6 Şubat 2015.

Tian, K., Endo, M., Urata, M., Mouri, K. &Yasuda, T. (2014). Multi-viewpoint smartphone AR-based learning system for astronomical observation. *International Journal of Computer Theory and Engineering, 6*(5), 396–400.

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. http://doi.org/10.1016/j.procs.2013.11.015

Üce, M., Özkaya, A. R. & Sahin, M. (2001). *Kimya eğitimi*. IV. Fen bilimleri eğitimi kongresi. Ankara: Hacettepe Üniversitesi Eğitim Fakültesi.

Ulusoy, F. (2011). *The effects of interventions based on chemical modelling and computer-based teaching over 12 graders' learning outcomes: The case of chemical bonding* (Doctoral dissertation). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 298547)

Ünal, S., & Benzer, A. İ. (2021). Modeling-based learning: A Content analysis on the studies published between 2004 and 2019 in Turkey. *Atatürk University Journal of Kazım Karabekir Education Faculty*, 42, 185-206.

Vaughan-Nichols, S. J. (2009). Augmented reality: no longer a novelty? *Computer*, *42*(12), 19-22.

Vergara-Díaz, C., Bustamante, K., Pinto, L., & Cofré, H. (2020). Exploring Chilean seventh grade students' conceptions of Earth dynamics before and after model-and inquiry-based instruction. *Journal of Geoscience Education*, *68*(4), 360-370.

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

Yen, J. C., Tsai, C. H. & Wu, M. (2013). Augmented reality in the higher education: students' science concept learning and academic achievement in astronomy. *Procedia-Social and Behavioral Sciences*, *103*, 165-173.

Yiğit, N., & Akdeniz, A. R. (2000). *Fizik öğretiminde bilgisayar destekli materyallerin geliştirilmesi; öğrenci çalışma yaprakları*. IV. Fen Bilimleri Eğitim Kongresi, Ankara: Hacettepe Üniversitesi Eğitim Fakültesi.

Zeynelgiller, O. (2006). *The effect of the use of models in chemistry subject of science lesson in secondary schools on students' success* (Master's thesis). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 196485)

Zeytinli-Ünal, M. (2018). *Teaching 8th grades "Living things and energy relations" unit with using models* (Master's thesis). Available from Thesis Center of The Turkish Council of Higher Education (YÖK Tez Merkezi). (Thesis No: 514221)

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