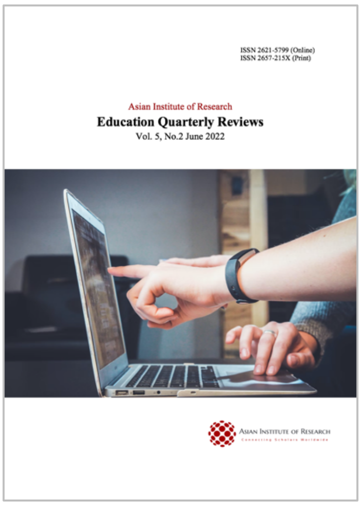

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The Impact of Augmented Reality-Based Argumentation Activities on Middle School Students' Academic Achievement and Motivation in Science Classes

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Abstract
Science teaching is one of the subjects that has been actively affected by Augmented Reality (AR) technology worldwide. Although the use of AR in science courses is increasing, the effective use of AR still needs improvement. The purpose of this study was to investigate the effect of augmented reality-based argumentation activities in 7th grade students' academic achievement and motivation in teaching astronomy content. The quasi-experimental design was used in this study. The participants consisted of 79 seventh-grade students from three different science classes. The students in experimental group 1 (n=26) participated in an instruction that included both augmented reality and argumentation activities about astronomy. The students in experimental group 2 (n=27) participated in an astronomy instruction that includes only argumentation activities and the students in control group (n=27) received astronomy instruction through traditional methods. The data were collected through pre-and post- academic achievement test and the Motivated Strategies for Learning Questionnaire (MSLQ). ANOVA and Kruskal Wallis tests were used to determine the statistical differences between the pretest and posttest scores of the students. The results showed that augmented reality-based argumentation activities were more effective in increasing students' achievement and motivation than the argumentation and traditional instruction in teaching astronomy.

Keywords: Augmented Reality, Argumentation, Science Education, Astronomy Education, Academic Achievement, Motivation

1. Introduction

The development in technology has resulted in a very important change in computer science and its use in different areas. Internet-related technologies and digital equipment have become a part of daily life for the new generation (Kennedy et al., 2008). In terms of access to information, this is the fastest phase of technological evolution ever (Palfrey & Gasser, 2011).

As schools try to cope with these new cultural and technological challenges, the technology continues to move towards more powerful GPS-enabled, location-based, WIFI-enabled handhelds capable of delivering high-quality multimedia, computing power (Dunleavy et al., 2009). Augmented Reality (AR) is one of the new technologies that emerged in this period. Azuma (1997) described AR as a change of virtual reality and stated that AR should have the features of 1) combination of reality and virtual, 2) real-time interaction, 3) registering in a three-dimensional environment. According to Cai et al. (2013), AR means integrating virtual objects into the users' environment through 3D graphics technology, computer vision, human-computer interaction, and multimedia techniques.

In many different areas, AR applications are created to use by independent groups and organizations. In the last 60 years, AR has been used in various fields (Cai, 2013) such as medical visualization, maintenance and repair, annotation, robot path planning, entertainment, and military aircraft navigation and targeting (Azuma,1997). In addition, it is also used in other fields such as informatics, advertising, design, and health. Education is one of the areas that has been actively affected by AR technology worldwide.

AR learning environments have various benefits in the teaching and learning process (Klopfer & Squire, 2008; Shelton & Hedley, 2002). AR motivates students and increases their participation (Kerawalla et al., 2006); it helps teachers to teach subjects where students cannot obtain first-hand experience all the time such as in the field of astronomy and geography (Shelton & Hedley, 2002), and helps students take control of the learning in their method and at their rate (Hamilton & Olenewa, 2010). A great number of researchers have studied the potential effect of AR in student learning. Studies emphasize that AR can eliminate students' misconceptions and improve their understanding of concepts (Cai et al.,2021; Chang et al.,2013; Shelton & Hedley, 2002; Yoon, et al., 2017), increases students' achievement (Chiang et al., 2014; Fleck & Simon, 2013; Sahin & Yilmaz, 2020; Sırakaya & Kilic Cakmak, 2018; Sin & Zaman, 2010; Yıldırım & Seckin Kapucu, 2021), triggers motivation (Kirikkaya & Başgül, 2019; Cai et al., 2013; Chang & Hwang, 2018; Chen & Liu, 2020; Lu et al.,2020; Yen et al., 2013), develops positive attitude (Sahin &Yılmaz, 2020; Hwang et al., 2016), generates self-efficacy (Cai et al., 2021) and helps students to understand complex abstract concepts (Abdüsselam & Karal, 2012; Shelton & Hedley, 2002; Sırakaya, 2015; Yuen et al., 2011). AR was integrated with different learning strategies in these studies such as collaborative learning (Baran et al., 2020, Chen & Liu, 2020), inquiry-based learning (Radu & Schneider, 2019), problem-based learning (Fidan & Tuncel, 2019) and argumentation (Jan, 2009; Squire & Jan, 2007) in science learning. In the current study, AR was integrated with argumentation in teaching astronomy content. There are only two existing research studying both AR and argumentation (Jan, 2009; Squire & Jan, 2007). Both studies were conducted in environmental education and location-based AR games were used to make students participate in argumentation. In astronomy education, studies integrating AR and argumentation have not been examined yet. In the current study, AR was used through handheld devices in teaching astronomy content to engage students in argumentation.

Many students perceive science as a difficult lesson because of the abstract concepts (Palmer, 1999). Especially, astronomy concepts are considered difficult to learn by students (Aktamış & Arıcı, 2013) because 3D spatial relationships include unobservable events but they are taught usually with 2D animations and photographs (Chen et al., 2007). Understanding complex abstract concepts, unobservable and difficult to visualize events is easier through AR technology that enables 3D representation of events and provides an understanding of topics that students find difficult (Aktamış & Arıcı, 2013; Pellas, et al., 2019; Yuen et al., 2011; Wu, Lee, Chang, & Liang, 2013).

Although the usage of AR in science education is increasing, adopting AR into teaching is slowly, teachers are still not ready to use AR in their class (Oleksiuk & Oleksiuk, 2020) and prefer not to utilize AR technology (Garzón et al., 2019; Romano et al., 2020). Because they lack the competence and motivation to create their own AR learning experiences (Dunleavy & Dede, 2014; Romano et al., 2020). Also, the adoption and implementation of educational technologies are more difficult and time-consuming than other methods (Parker & Heywood, 1998). However, teachers who can not use existing technology will face significant difficulties, as they provide education for 21st-century students who use computers, mobile phones, tablets, the internet, and other technology devices every day (Aksoy, 2003; Reiner, 2009). Teachers need to follow up and keep up with innovations like AR and use them as part of their teaching practice. Therefore, the current study has the potential to contribute to the usage of AR in science classes and how science teachers can integrate AR technology into class.

1.1 Argumentation and Augmented Reality

It is difficult for science teachers to develop learning strategies that engage students in inquiry in which they develop scientific thinking skills (Squire & Jan, 2007). Argumentation is a critical component of learning that facilitates scientific thinking and reasoning (Voss & Means, 1991) and it has a crucial role in knowledge construction (Walker & Sampson, 2013). The more students engage in argumentation, the more scientific thinking and reasoning skills they could develop (Nussbaum et al., 2012). Especially it is very important to engage students in argumentation in science classes and support them to construct more consistent and evidence-based arguments in Covid 19 pandemic process (Erduran, 2020). To construct more consistent and evidence-based arguments, supportive elements such as visual tools should be used (Akpınar et al., 2014). Meaningful connections in discussions increase (Erkens & Janssen, 2006), and more detailed communication about arguments was established with enriched visual tools (Jermann & Dillenbourg, 2003).

The students observe the behaviour of the objects (Clark et al., 2007), obtain different perspectives on the subject (Oestermeier & Hesse, 2000), comprehend presentations of scientific facts that are difficult to understand through textual or oral explanations (Cadmus, 1990) and find evidence for their arguments by the help of enriched visual representations (Clark et al., 2007; Jermann & Dillenbourg, 2003). One of the contemporary and cutting-edge visual tools is AR that provided rich data source for students' arguments. AR provides a real-world environment and real-time interaction to students enriched with 3D models by merging virtual objects with the real environment in 3 dimensions (Kerawalla et al., 2006). Models that students can interact with, enhance information acquisition and permit deeper understanding (Thornton, Ernst, & Clark, 2012). In this way, students collect data and evidence to support or refute the arguments. Studies conducted with AR technology concluded that all students participated in argumentation and constructed arguments (Squire & Jan, 2007; Jan, 2009). However, the variables such as academic achievement and motivation have not been examined using AR technologies integrated with argumentation.

The purpose of this study is to examine the effect of augmented reality-based argumentation activities in 7th grade students' academic achievement and motivation in teaching astronomy content.

Following research questions were addressed:

1. Is there a significant difference between the academic achievement scores of students in three different instructional interventions?
2. Is there a significant difference between motivation towards science and technology course of students in three different instructional interventions?

2. Method

The non-equivalent groups design is used as one type of quasi-experimental design. In quasi-experimental design, the members in the groups are not selected randomly, the experimental and control groups are formed with existing classes (Cohen et al., 2000).

2.1 Participants and Context

The participants consisted of 79 seventh grade middle school students determined by convenience sampling method; 26 were in the experimental group 1;17 females and 9 males. 27 were in experimental group 2;13 females and 14 males. And 26 were in the control group; 13 females and 13 males. Three groups of students were randomly assigned in one of the groups called experimental group 1, experimental group 2 and control group (Cohen et al., 2000). The ages of students were between 12 and 13 and were from high socio economic status (SES) families.

The interventions in all groups were carried out by one of the researchers. Because the use of AR technology in science education was new when the study was conducted and science teachers lacked the ability to use AR technology. Before the implementation, the researcher participated in classes with the teacher of the course and made observations. The reliability of the implementation of instructions and data collection was increased by this prolonged engagement (Guba & Lincoln,1989).

2.2 Interventions

A three-weeks 19-hours intervention was carried out for each group. Students in experimental group 1 received instruction that included AR-based argumentation activities about astronomy. The students in experimental group 2 engaged in astronomy instruction based on argumentation activities and the students in the control group received traditional astronomy instruction. The control group instruction did not contain either AR or argumentation activities. Figure 1 shows the interventional process of the study.

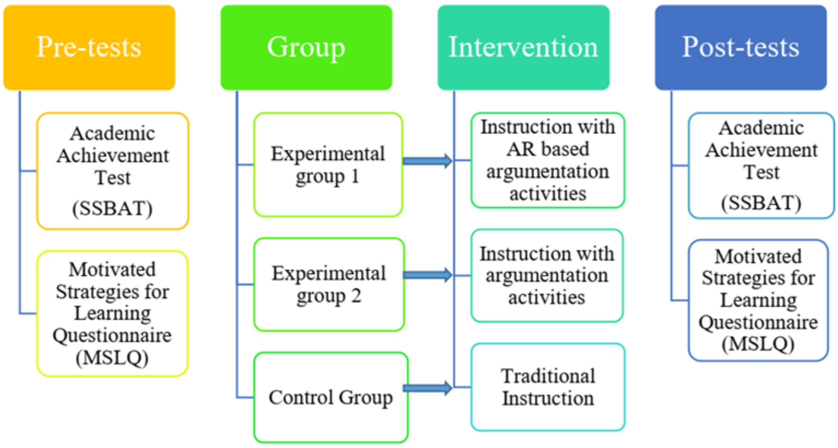

Figure 1: The interventional process of the study

2.2.1 AR activities

Students in experimental group 1 engaged in AR activities integrated with argumentation. AR activities were conducted with students' tablet computers through free applications such as i-solar system, Aurasma, Junaio, Sky view Free, Augment and Star Chart. Videos, simulations, and 3D visuals about astronomy in Augment and Aurasma applications were used as "overlays" during the activities. "Trigger images" were photographs, coloured areas and pictures in the students' textbooks and worksheets. Junaio browser app was used for the mobile applications of the planets in "Augmented Reality Magic Book: Solar System." The students could interact with and manipulate these videos, simulations, and 3D visuals during the AR activities.

Students made sky observations through "Sky View Free" and "Star Chart" applications. The school administration supplied tablet computers from their stock. The AR activities are given in detail in Appendix A.

2.2.2 Argumentation Activities

Argumentation activities were performed with experimental group 1 and experimental group 2 students. The students were divided into six groups by the teacher, each consisting of four students, paying attention to heterogeneity in terms of gender and success before the instruction. The students engaged in whole-class discussions after small group discussions. Table of statements, Predicting-Observing-Explaining, Competing Theories Cartoons and Argument Driven Inquiry (ADI) frameworks were used in argumentation activities. ADI consists of eight steps called "identification of the task, the generation and analysis of data, the production of a

tentative argument, an argumentation session, an investigation report, a double-blind peer review, revision of the report, and explicit and reflective discussion” (Sampson & Gleim, 2009; Sampson, Grooms & Walker, 2011). Due to the limited time, the last two steps of the ADI method were not performed in this study.
The argumentation activities are given in detail in Appendix B.

2.2.3 Activities used in control group

Traditional astronomy instruction suggested by the curriculum was used in the control group. The activities used in the control group were similar to the activities used in the experimental groups. But the activities did not include either AR technology or argumentation. For example, experimental group 1 students observed the moon phases using AR and then small groups consisting of four students participated in argumentation. The students in experimental group 2 observed the moon phases in small groups through modelling which includes small balls that represent earth, moon, sun. Then small groups consisting of four students participated in argumentation. The control group students only observed the moon phases through modelling. They did not engage in argumentation or use AR technology for the observation.

2.3 Data Collection

The data were collected through an academic achievement test about astronomy and Motivated Strategies for Learning Questionnaire (MSLQ).

2.3.1. "Solar System and Beyond: Spacecraft" unit academic achievement test (SSBAT)

An achievement test was developed by the researcher to determine the academic achievement of the students for the "Solar System and Beyond: Spacecraft" unit. The test consisted of 40 questions used from TIMMS 2007 (Trends in International Mathematics and Science Study), PISA (Programme for International Student Assessment), Astronomy Diagnostic Test, course books, the Ministry of National Education’s terminal exams, Deniş Çeliker’s (2012), Arici’s (2012) and Baltacı’s (2013) studies. Three experts from the department of science education; (one of them held a PhD degree in astrophysics) and a science teacher examined the content validity of the test. Some questions were changed in line with expert views and two questions were removed from the test. The test consisted of 38 questions were given to 140, 8th-grade students for the pilot implementation. Item analysis was carried out by ITEMAN software for the pilot implementation. After the required changes, the final version of the test consisted of 30 questions. With a reliability value of .84 using the Kuder Richardson-20 (KR-20) scale, the pilot test was considered reliable. The reliability value of the test in the main implementation was .71 for the pre-test and .70 for the post-test.

2.3.2. Motivated Strategies for Learning Questionnaire (MSLQ)

Motivated strategies for learning questionnaire (MSLQ) was constructed to assess students' motivation and learning strategies in a course context (Pintrich et al., 1993). The latest version of MSLQ developed by Pintrich et al. (1993) consists of motivational and learning strategies subscales. The motivation section of the questionnaire consists of 31 items and six subscales composed of intrinsic goal orientation, extrinsic goal orientation, task value, control of learning beliefs, self-efficacy for learning and performance, and test anxiety. The learning strategy section consists of 50 questions and nine subscales. The items of the questionnaire use a seven-point rating scale (1= not at all true for me, 7= very true for me. The MSLQ consists of two sub-scales and the scores obtained from the subscales can be used partly according to the purpose of use of the researcher (Pintrich et al. (1991). So, in the current study, only the motivation section was used to assess students’ motivation.

The Turkish version of the MSLQ was adapted to Turkish by Sungur (2004) and it was found reliable. In the current study, the questionnaire was used for the science and technology course and the reliability coefficient for the motivation section was .87. The reliability coefficients were .67 for intrinsic goal orientation, .68 for extrinsic goal orientation, .77 for task value, .89 for control of learning beliefs and self-efficacy for learning and performance, and .73 for test anxiety.

2.3 Data Analysis

ANOVA was used to determine whether there was a significant difference between the pretest and posttest mean scores of the students' "Solar System and Beyond: Spacecraft" unit academic achievement test. To determine whether there was a significant difference between students' motivation towards science and technology courses, the Kruskal Wallis H test was used because the data did not correspond to a normal distribution.

3. Results

3.1 Academic achievement

ANOVA was carried out to determine whether the pre-test and post-test scores of the students in the experimental and control groups showed significant differences. Before implementation, Tamhane's Post Hoc Test was conducted, due to the Levene Homogeneity test results. There was no significant difference between the pre-test SSBAT's mean scores of the groups (Xexperimental 1= 13.27 sd=4.01, Xexperimental 2= 15.48 sd=5.57, Xcontrol=14.23 sd=3.79, p>.00). Descriptive statistics for SSBAT's post-test scores were examined when ANOVA assumptions were met. Descriptive statistics for SSBAT post-test scores are given in Table 1.

Table 1: Descriptive Statistics of the SSBAT's posttest mean scores

GROUP	N	$\bar{X}$	SD
Experimental group 1	26	25.96	2.51
Experimental group 2	27	23.63	3.11
Control group	26	22.07	3.67

The ANOVA results of SSBAT mean scores of the groups are presented in Table 2.

Table 2: ANOVA Results of the SSBAT's postest mean scores

	Sum of squares	df	Mean square	F	p
Between groups	198.87	2	99.44	10.14	.00*
Within groups	745.10	76	9.80		
Total	943.98	78			

ANOVA results showed that there was a significant difference between the posttest achievement mean scores of the groups (F 2-78= 10.14, p = .00). The Scheffe test was used as post hoc to find out where the significant difference occurred among the three groups' means scores and the results are presented in Table 3.

Table 3: The Scheffe test results related to the SSBAT's mean scores

Group (i)	Group (j)	xi-xj	SE	p
Experimental group 1	Experimental group 2	2.33	.86	.03
Experimental group 2	Control	1.55	.86	.20
Control	Experimental group 1	-3.88	.87	.00

Results from Table 3 indicate that there was a significant difference between post-test mean scores of students in the experimental groups and control group in favor of the experimental group 1 whereas there was no significant difference between the experimental group 2 and the control group.

3.2 The motivation of students

To determine whether there was a significant difference between students' motivation towards science and technology course, the Kruskal Wallis H test was used because the data did not correspond to a normal distribution. The results were presented in Table 4.

Table 4: Kruskal Wallis H Test results of the groups' gain scores on motivation

Subdimensions	Group	n	Mean rank	df	$\chi 2$	p
Intrinsic Goal Orientation	Experimental group 1	26	53.46	2	13.85	.00
	Experimental group 2	27	32.48			
	Control	26	34.35			
Extrinsic Goal Orientation	Experimental group 1	26	47.73	2	6.13	.00
	Experimental group 2	27	39.65			
	Control	26	32.63			
Task Value	Experimental group 1	26	55.12	2	18.89	.05
	Experimental group 2	27	28.83			
	Control	26	36.48			
Control of Learning Beliefs	Experimental group 1	26	52.50	2	12.13	.00
	Experimental group 2	27	34.09			
	Control	26	33.63			
Self-Efficacy for Learning and Performance	Experimental group 1	26	52.54	2	12.88	.00
	Experimental group 2	27	30.70			
	Control	26	37.12			
	Experimental group 1	26	33.69	2	2.96	.23
Text anxiety	Experimental group 2	27	43.35			
	Control	26	42.83			

The results of the Kruskal-Wallis H test indicated that there was a significant difference between the groups in all subdimensions of the MSLQ except "test anxiety." Mann Whitney U test were conducted to evaluate pairwise differences among the three groups. The results were given in Table 5.

Table 5: Comparison of the MSLQ post-test gain scores of the groups (Mann Whitney U Test)

Subdimension	Group	N	Mean rank	Rank sum	U	p
Intrinsic Goal Orientation	Experimental group 1	26	34.27	891.00	162.00	.00
	Experimental group 2	27	20.00	540.00		
	Experimental group 1	26	32.69	850.00	177.00	.00
	Control	26	20.31	528.00		
	Experimental group 2	27	26.48	715.00	337.00	.80
	Control	26	27.54	716.00		
Extrinsic goal orientation	Experimental group 1	26	29.52	767.5	285.50	.23
	Experimental group 2	27	24.57	663.5		
	Experimental group 1	26	31.71	824.50	202.50	.00
	Control	26	21.29	553.50		
	Experimental group 2	27	29.07	785.00	295.00	.29
	Control	26	24.85	646.00		
Task Value	Experimental group 1	26	35.40	920.50	132.5	.00
	Experimental group 2	27	18.91	510.50		
	Experimental group 1	26	33.21	863.50	163.50	.00
	Control	26	19.79	514.50		

	Experimental group 2	27	23.93	646.00	268.00	.13
	Control	26	30.19	785.00		
Control of Learning Beliefs	Experimental group 1	26	33.27	865.00	188.00	.00
	Experimental group 2	27	20.96	566.00		
	Experimental group 1	26	32.73	851.00	176.00	.00
	Control	26	20.27	527.00		
	Experimental group 2	27	27.13	732.50	347.50	.95
	Control	26	26.87	698.50		
Self-Efficacy for Learning and Performance	Experimental group 1	26	34.17	888.50	164.50	.00
	Experimental group 2	27	20.09	542.50		
	Experimental group 1	26	31.87	828.50	198.50	.01
	Control	26	21.13	549.50		
	Experimental group 2	27	24.61	664.50	286.5	.24
	Control	26	29.48	766.50		

The results of the Mann Whitney U test showed that the gain scores of the students in the experimental group 1 in all sub-dimensions of MSLQ except for the “extrinsic goal orientation” sub-dimension, were significantly different than the gain scores of the experimental group 2 and the control group students. In the “extrinsic goal orientation” dimension, there was a significant difference between experimental group 1 and control group but there was no significant difference between the gain scores of experimental group 1 and experimental group 2. No significant difference was found between the gain scores of the experimental group 2 and control groups in any of the sub-dimensions.

4. Conclusion and Discussion

Results showed that students in experimental group 1 engaged in the learning process that includes both AR and argumentation activities about astronomy had higher scores of achievement test than the experimental group engaged only in argumentation activities about astronomy and the control group engaged in traditional intervention. But there was no significant difference between the experimental group 2 and the control group. In line with these results, it can be claimed that the reason for the high academic success of the experimental group 1 is due to the AR technology. In parallel with the results, it has been reported in the literature that AR technology increases achievement (Chiang et al., 2014; Fleck & Simon, 2013; Sahin & Yilmaz, 2020; Sırakaya & Kilic Cakmak, 2018; Sin & Zaman, 2010; Yıldırım & Seckin Kapucu, 2021). For example, in the study of Sin and Zaman (2010) conducted with middle school students to determine the usability of the book developed using AR technology on the Solar System, on the ease of use, learnability and effectiveness, it was concluded that experimental group students' success was higher than the control group students. Similarly, Sirakaya and Kilic Cakmak (2018) conducted a study to investigate the effect of AR on students' achievement, misconception and course engagement and they found that AR technology increased the achievement level of students and the experimental group had fewer misconceptions than the control group.

The reason for the high achievement of the students in experimental group 1 in the current study could be that the AR technology increased the motivation of the students and facilitated their learning. The AR technology was very new in science education when the study was conducted so it attracted the attention of students. Gurian and Stevens (2005) defined the motivational process as a process that tries to understand and achieve success by studying biochemistry, neurotransmitters and nerve tissue (cited in Rogers, 2014). Applegate and Applegate (2010) also stated that one of the most important factors affecting student achievement is motivation.

For middle school students, astronomy has abstract concepts that science teachers have difficulty in teaching (Aktamış & Arıcı, 2013). The fact that AR technology facilitates learning by concretizing the subjects, eliminating misconceptions, and providing retention could be a reason for the increase of students' achievement. Researchers have stated that AR technology helps students to understand complex abstract concepts and that it is a technology that can be used for unreachable things, unobservable and difficult to visualize events and enables them to understand subjects with learning difficulties (Aktamış & Arıcı, 2013; Cai et al., 2013; Kerawalla et al., 2006; Pellas et al., 2019, Yıldırım & Seçkin Kapucu, 2021; Yuen et al., 2011). Abdüsselam and Karal (2012) concluded that AR environments are an advantage in students' understanding of physic concepts and transforming it from abstract to concrete. In Sırakaya's study (2015), the students stated that the implementation concretized abstract issues. Fleck and Simon (2013) determined that the AR system used on the phases of the Moon with 4th and 5th-grade students eliminated the misconceptions and significantly improved astronomy learning. In the study conducted by Zhang et al. (2014) on stars and constellations with fifth-grade students, the effect of AR on retention was investigated, and at the end of the implementation, it was found that there was a significant difference in favour of the experimental group in the retention tests.

The use of tablets as a mobile learning tool in the study can also be associated with the increase in the success of experimental group 1. With mobile learning, students can have the opportunity to learn whenever and wherever they want (Kamphuis et al., 2014). Students' being able to access learning materials prepared with AR technology whenever they want may be a factor in increasing their achievement.

In addition to emphasizing that AR technology increases achievement, it was also found in some studies that AR technology does not have a significant effect on achievement. In the study of Cai et al. (2013) with eighth-grade students, the students' success on the thick-edged lens experiment was examined and at the end of the study, it was found that although the average scores of the experimental group students were higher than the control group, there was no significant difference between the two groups. Abdüsselam and Karal (2012) examined the effect of the AR technology on the academic achievement of 11th-grade students in the "Magnetism" unit and no significant difference was found between the two control groups using the traditional method and the experimental group. Disparities in the results of the studies suggest that physical activities may be more effective in concrete subjects and when using realia. Researchers have stated that AR applications enable students to embody many abstract objects and experiments and that it is an approach that can be used for unreachable things (Aktamış & Arıcı, 2013; Cai et al., 2013; Kerawalla et al., 2006; Pellas et al., 2019; Yuen et al., 2011). Cheah et al. (2014) stated that AR may not always be the most effective learning tool, sometimes more traditional methods may be more effective in the learning process, and some students prefer physical models over virtual simulations. Similarly, Jonk et al. (2013) stated that sometimes, virtual research may be equal to or more effective than physical research, and at other times physical laboratories may be more appropriate than virtual laboratories. According to Jonk et al. (2013), virtual laboratories are effective when students investigate situations that cannot be done with physical research and cannot be observed. Kozma (1991) emphasized that even though children learn equally with different tools, some methods are specific to a certain environment.

In the current study, it was found that the gain scores of the students in the experimental group 1 in all sub-dimensions of MSLQ except for the "extrinsic goal orientation" sub-dimension, were significantly different than the gain scores of the experimental group 2 and control group students. No significant difference was found between the gain scores of the experimental group 2 and control groups in any of the sub-dimensions. Considering this finding it can be claimed that the AR applications with argumentation are more effective than other methods in increasing motivation. While there was a significant difference between the gain scores of experimental group 1 and experimental group 2, and between experimental group 1 and control group, the fact that there was no significant difference between the gain scores of experimental group 2 and the control group leads to the conclusion that AR technology creates this difference.

Similar results have been reported in the literature (Kirikkaya & Başgül, 2019; Cai et al., 2013; Chang & Hwang, 2018; Chen & Liu, 2020; Lu et al.,2020; Yen et al., 2013). Intrinsic motivation is self-motivation and results in enjoying the process of enhancing one's competence in terms of certain academic tasks (Ryan & Deci, 2000). Individuals were internally motivated when they had fun, were interested, wondered (Deci et al., 1991; Malone, 1981), participated in the activity (Deci et al., 1991), and had difficulty (Malone, 1981). The AR technology was very new when the current study was conducted and the students had no experience with AR technology in their science class before. So, it is thought that the activities performed with AR technology, which is a new technology, cause students to be surprised, arouse curiosity and emotional reactions. The findings of this study also concluded that AR technology motivated the students internally.

5. Limitations and Future Research

This study has some limitations. First, the sample size was not big enough to generalize the results of the study. This study was conducted with students from high socio-economic status. To generalize the results, the future researcher can select more participants from both low and middle SES families. The students participated in an instruction that included both AR and argumentation activities in about "Solar System and Beyond: Spacecraft" unit. It was concluded that the AR technology-based argumentation activities were more effective in increasing the academic achievement and the motivation of the students. In future research AR-based argumentation activities can be developed and used in different topics of science. Because AR was a new technology in science education and teachers had inadequate knowledge and experience about AR technology when the study was conducted, one of the researchers of the study carried out the lesson in all groups. Teachers need to develop their own AR experiences to present the learning effects of AR available to a wider audience (Romano et al., 2020). This study was conducted with a quasi-experimental design. Action research with the science teacher who is the instructor can be carried out to examine the learning outcomes and problems experienced in implementation.

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Appendix A

The activities performed with augmented reality technology

Activities	**Content**	**AR applications used in activities**
My constellation story	Designing a constellation, preparing a poster with information about this constellation, creating a story about the constellation, recording the narration of this story with video and superimposing the video on the poster through Aurasma	Aurasma
Meteor shower	Watching a video of a meteor shower superimposed on textbook	Aurasma
The moon and planets	Observing three-dimensional images of the moon and planets superimposed on a textbook	Blender and Aurasma
Space shuttle and the moment the shuttle launches	Observing a 3D image of the space shuttle with the Augment app. and the first launch moment of the shuttle superimposed on a textbook with Aurasma.	Augment and Aurasma
Moon, Earth, Telescope, Space Shuttle	Observing the rotation of the moon in its orbit around the Earth, the 3D telescope and the space shuttle view	Augment
The Planets	Exploring 3D models, videos, images and sounds about planets in the "Augmented Reality Magic Book" created by Nedim Slijepcevic and Wanju Huang	Junaio
Solar System	Interactively observing the solar system	i Solar System book and its application
First landing on the moon	Examining the first landing on the moon while this is happening in front of you in an immersive virtual world	Moon walking
Sky Observation	Observing the sky (the current position of every star and planet visible from the Earth and where they are and 3D effects, distances, brightness and positions of stars, constellations and planets)	Star Chart, Sky View

Appendix B
Activities performed with argumentation

Activities	**Content**	**Argumentation Frameworks**
Who is right?	To engage in argumentation on the question of whether astrology is a science or not.	Competing Theories-Cartoons
The planets-table of Statements	To engage in argumentation whether the statements in the presented table about the planets are true or false.	Table of Statements
The phases of the moon	To explain the following: What are the phases of the moon and why do we see them in the order we do? Why do we see the same side of the moon every day?	Argument Driven Inquiry (ADI)
Urgent solution to space pollution	Making arguments about preventing space pollution	Constructing an argument