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Effectiveness of augmented reality implementation methods in teaching Science to middle school students

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Abstract

The aim of this study was to determine the effectiveness of the Science teaching process to middle school students using teaching materials prepared via augmented reality (AR) technology. In the experimental study, 61 sixth grade students at a middle school in Antalya in the 2019-2020 academic year were selected randomly, and the mixed research design was utilized to understand the academic achievements of students and their' opinion about the augmented reality implementations in Science classes. In the study, the control group were taught through the science curriculum prescribed methods, and the experimental group were taught using augmented reality implementations, and these groups were compared in terms of their achievement. The quantitative data were collected via an achievement test, and the qualitative data were collected via an interview form. The quantitative and qualitative data were analyzed using t-test and descriptive data analyses methods. As a result of the study, it was revealed that AR implementations contributed positively to students' science learning processes, and it increased their academic achievement. It was also shown that AR implementation contributed to students' meaningful learning by making abstract subjects concretized, and at the same time it increased students' interest and motivation in Science lessons.

Keywords: Augmented reality implementations; science teaching; science education; systems in our body

1. Introduction

While the developments in technology have increased rapidly, these developments directly affect the information technologies, the use of which is increasingly widespread. Especially developments in information technologies offer new opportunities in different disciplines. Different practices and experiences are offered in disciplines such as communication and education, benefiting from the developments in this field. As a result of the developments in these areas, learning tools have also changed and rich learning environments are offered to students with technology-based experiences (Sayımer &

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Küçüksaraç, 2015). Today, what we call the information age, learning and learning environments should be designed in accordance with the age. It is believed that learning environments designed by considering environmental conditions, expectations and technological developments will positively affect the permanence and quality of learning (Akkoyunlu, 2002). At this point, augmented reality implementations that have come to the fore in recent years have attracted attention and their use in learning environments is becoming widespread. This situation draws the attention of both educators and researchers (Matcha & Rambli, 2013).

The concept of augmented reality was born in 1970s as a result of the development of the studies carried out by Ivan Sutherland and his students in Harvard and Utah universities in the 1960s (Çankaya & Girgin, 2018). It was first used in the air and space activities of the USA and its use became widespread in the 1990s (Feiner, 2002). Augmented reality is a technology that enables visual and real objects to be displayed together in a digital layer through different implementations and objects (Abdüsselam, 2014; Abdüsselam & Karal, 2012; Çınar & Akgün, 2015; Uluyol & Eryılmaz, 2014). In other words, augmented reality technology is the environments where people interact with virtual objects placed on the real world environment and is abbreviated as "AR" (Çankaya & Girgin, 2018). In Turkish, this concept is translated as “Artırılmış Gerçeklik” and abbreviated as “AG”. The concepts of augmented reality and virtual reality are often compared and sometimes confused due to their content and the similarity of the tools used. While virtual reality is a completely artificial environment, both artificial and real environments are presented together in augmented reality and therefore it is known that augmented reality is a derivative of virtual reality (Azuma, 1997). In other words, AR is a virtual reality implementation where users experience reality in a digital environment with virtual objects without changing the real environment (Zhu, Owen, Li, & Lee, 2004).

Due to its versatile utilization possibilities and numerous advantages, it is possible to use augmented reality based implementations in different educational areas and at different levels. These advantages and versatility includes, teaching of objects and events that cannot be seen through human eye, displaying dangerous situations, concretizing abstract concepts and presenting complex information, easier access to materials used in learning environments, meeting the necessary educational needs more conveniently, guiding the practices in the process, creating creative and original environments, improving student-student or student-teacher interaction and adapting to technology and so on (Kerawalla, Luckin, Seljeflot, & Woolard, 2006; Küçük, Yılmaz & Göktaş, 2014; Özarslan, 2011; Venkatesh, Morris, Davis, & Davis, 2003; Walczak, Wojciechowski, & Cellary, 2006). Although it is stated that AR-based implementations are beneficial for the educational environment, it is emphasized that more studies in this area are necessary in terms of examining the different variables in learning environments where AR technology is used and the relationships between these variables (Martin, Diaz, Sancristobal, Gil, Castro, & Peire, 2011; Wu, Lee, Chang, & Liang, 2013). It may not always be possible to use new technologies in education. Internal decision-making

processes are of great importance in the acceptance of these innovations by individuals in the educational environment. When individuals see the new technology as easy to use and useful, they show a positive attitude towards those new technologies, and this leads to the widespread use of these technologies (Karagözlü & Özdamlı, 2017; Rizov & Rizaova, 2015; Venkatesh, Morris, Davis, & Davis, 2003). "The educational value of augmented reality implementations depends not only on the use of technologies, but also on how the augmented reality implementations are designed, implemented and integrated into learning environments. For this, factors such as students 'motivation, teachers' condition and whether they are prone to this method are important "(Durak, Karaoğlan Yılmaz, 2019). When the literature is scanned, it is seen that although there are studies that examine students' attitudes, motivation, anxiety, success and perceptions with educational activities carried out with AR implementations in different fields, more studies should be conducted on these subjects. As a matter of fact, the aim of this study carried out in the light of this information is to increase the value of students' learning levels of science achievement (Buluş Kırıkkaya, & Şentürk 2019; Chen & Wang, 2015; Hsiao, Chen & Huang, 2012; Hwang, Wu, Chen & Tu, 2016; Shelton & Hedley, 2002; Sırakaya & Alsancak Sırakaya, 2018; Vilkoniene, 2009; Zhang, Sung, Hou, & Chang, 2014) and to raise the attention, interest and motivation of students towards learning science to higher levels. For this purpose, AR implementations were carried out in the science course. Teaching science subjects with Augmented Reality implementations increases the importance of research in the field of science education. In this study, it was aimed for students to explore the structure and organelles of the cell in three dimensions with an augmented reality implementation.

In line with this goal, teaching activities (science cards) supported by A.R technology were designed for the "Systems in our Body" unit of the 6th grade science curriculum and the effect of these activities on students' academic achievement and whether they increase their interest and motivation towards science learning was examined. For this purpose, answers to the following questions were sought:

1. Is there a significant difference between the pre-test scores of the experimental and the control groups?
2. Is there a significant difference between the post-test scores of the experimental and the control groups?
3. What are the opinions of the students in the experimental group about the implementation of the Augmented Reality (AR) method?

2. Method

2.1. Research model

The study adopted experimental experimental-control groups research design, and the data were collected using mixed method base on both qualitative and quantitative data.

Mixed method research offers an alternative approach to the researcher in reaching the goals of "reaching depth and detail" where quantitative research methods are known to be insufficient and "generalizing and making predictions" which are the weaknesses of qualitative research methods (Yıldırım & Şimşek, 2013). Davies (2000) states that combining qualitative and quantitative methods in a single study helps to explain various aspects of the investigated phenomenon by providing a more holistic understanding and creating better informed education policies.

Table 1: Research Pattern

Groups	Before implementation	Implementation Method	After implementation
Experimental	Pre-Test (Test1)	Augmented Reality	*Post-Test (Test1) *Interview Form
Control	Pre-Test (Test1)	The science curriculum prescribed methods	*Post-Test (Test1)

In order to support the quantitative data, the opinions of the students in the experimental group about the implementation were taken and the qualitative documents created during the implementation were used.

2.2. Study Group

The study group of the research consists of 6th grade students studying at a middle school in Antalya in the 2019-2020 academic year. A total of 61 students, 30 in the experimental group and 31 in the control group, participated in the study and the groups are assigned through unbiased election.

Table 2. Number of students participating in the study

	Female	Male	Total
Control Group	17	14	31
Experimental Group	18	12	30
Total	35	26	61

2.3. The Process of Performing Experimental Procedures

This research was carried out with the participation of 6th grade students in a middle school in Antalya city. After the subjects to be used in the experimental process of the research (Systems in our Body) were determined, the AR implementations to be used regarding the subjects were designated and the material (Science Cards) to be used

during the Augmented Reality implementation was obtained via the internet. Before the implementation, the experimental group students were informed about how the implementation would be carried out. The implementation process was carried out by the same teacher in the experimental and control groups. While the teaching process in the experimental group was carried out by using AR-based materials, the students in the control group were taught these images based on a two-dimensional textbook. In the experimental group, AR implementations were used on appropriate subjects for six weeks. The photographs taken during the augmented reality implementation to the experimental group are shown in Figure 1.

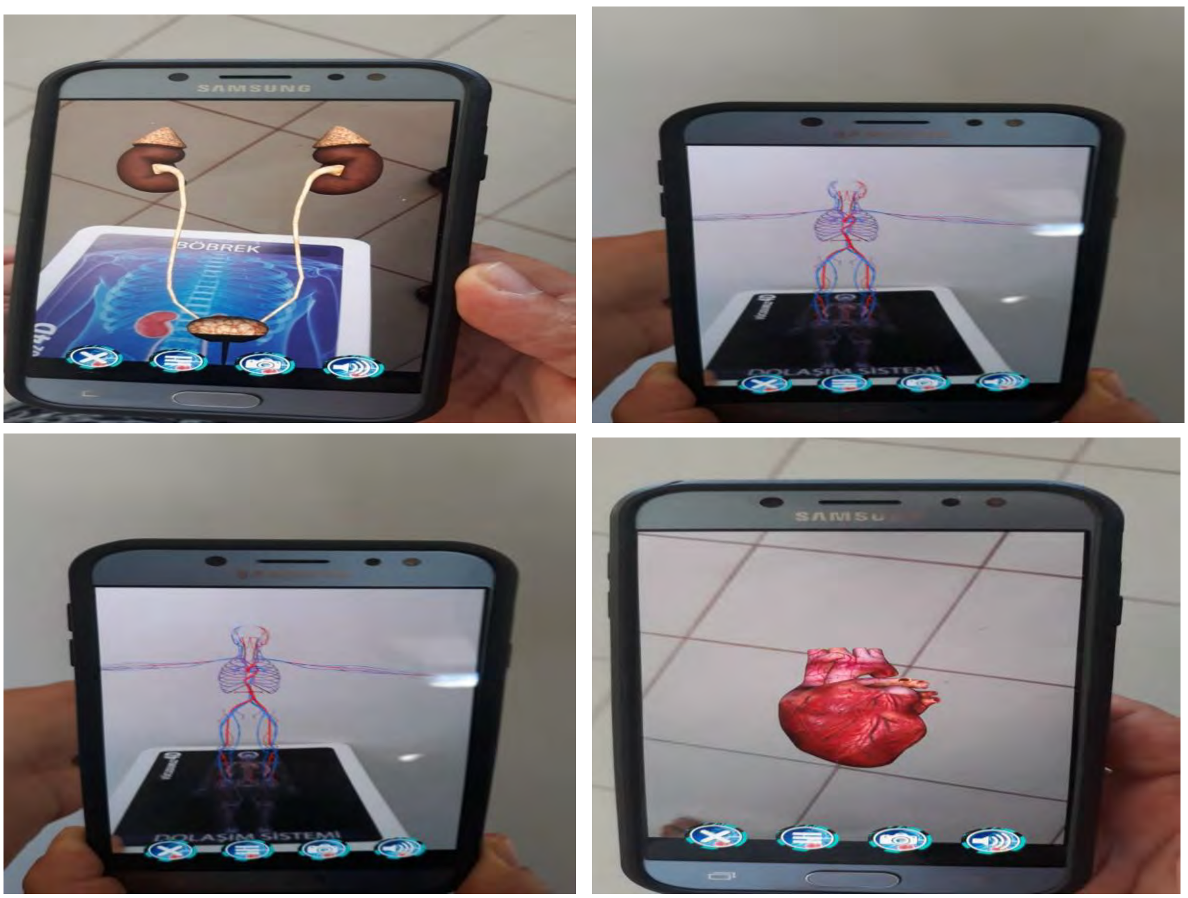

Figure 1. Examples of the implementations made by the experimental group students

2.4. Reliability and validity of data collection tools

The data collection tools used in the study are the achievement test prepared for the "Systems in our Body" of the Science curriculum and a semi-structured student interview form that includes student views about the implementation.

2.4.1. Achievement test

A 20-question multiple-choice test was prepared as a data collection tool for the study in line with the acquisitions of the “Cell and Divisions” unit of the 6^{th} grade curriculum in order to be administered to the experimental group and the control group. The test was prepared in a way to cover all the gains of the unit and its content validity was ensured. A total of seven experts, two science education academics and five experienced science teachers, were interviewed about the adequacy of the test in measuring unit gains, whether it contained scientific errors and the comprehensibility of the questions. The questions have been revised in line with the opinions of the experts. The final version of the test was solved by two 7th grade students and feedback was received from the students about whether they understood the questions. In line with the feedback received from the students for the final version of the test and test was finalized after some small revisions made. The final version of the test was administered to a group of 220 seventh grade students at another school. The KR-20 reliability coefficient of the achievement test was found to be 0.80.

2.4.2. Interview form

As a result of the review of the relevant literature, interview questions consisting of open-ended questions were prepared during the preparation of the student interview form in order to get the opinions of the students consisting the experimental group. The form prepared was revised in line with the feedback received from 2 field experts. In order to determine whether the questions in the form were understood or not, the questions were asked to two seventh grade students, then the questions were given their final form and directed to the students in the experimental group.

2.5. Data collection process

Before the start of the implementation, an achievement test suitable for the levels and acquisitions of the students was prepared. The achievement test prepared was administered as a pre-test to both experimental and control group students before the research. After the lessons were completed via AR implementations in the experimental group, and via the science curriculum prescribed methods in the control group, the achievement test was administered as a post-test. In order to support the quantitative data, the opinions of the experimental group students about the AR implementation were taken.

2.6 Data Analysis

2.6.1 Analysis of Quantitative Data

In the research, quantitative data were obtained with the success test prepared on the relevant subject, and these data were analyzed with the t-test.

2.6.2 Analysis of Qualitative Data

Descriptive analysis and content analysis techniques were used in the analysis of qualitative findings. The main framework for the qualitative data to be collected in the descriptive analysis was determined depending on the research problem, and direct quotations were made from the interview data after making relevant inferences from the data. Inferences made from the data obtained during the descriptive analysis were supported by direct quotations. Qualitative data collected during the content analysis phase were classified under certain categories. At this stage, the main themes determined based on the categories for qualitative analysis were included, analyzes were made under these main themes, and the analyzes were supported with the quotations obtained in the descriptive analysis (Yıldırım & Şimşek, 2013).

3. Findings

In this section, quantitative and qualitative findings will be given under separate headings.

3.1 Quantitative Findings

Table 3: Pre-test average scores of research groups

	Groups	*N*	*Mean*	*Std. Deviation*	*p*
Success	Experimental_pre-test	30	35,2280	14,47935	0,670
	Control_pre-test	31	33,1610	11,58285	

When Table 3 is examined, it is seen that the average score of the experimental group students of the study is 35.22, and the average score of the control group students is 33.16. The statistical significance of the difference between the mean scores of the groups was compared with the independent t test. The difference between the arithmetic averages of the scores between the groups in the pre-test implementation of the achievement test of both groups is not statistically significant ($p > 0.05$). After the implementation, the academic achievement test was administered to the control and experimental groups as a post-test. Analysis results of the post-test results of the groups are given below.

Table 4: Post-test average scores of the groups participated in the study

Groups	*N*	*Mean*	*Std. Deviation*	*P*

Success	Experimental post-test	30	78,5305	22,82305	0,035
	Control post-test	31	65,3299	26,07664	

According to the data of Table 4, it is seen that the average score of the experimental group students of the study is 78.53 and the control group students 65.32. The statistical significance of the difference between the mean scores of the control and experimental groups was compared with the independent t test. The difference between the arithmetic averages of the scores between the groups in the post-implementation achievement test of the experimental and control groups is statistically significant and in favor of the experimental group ($p < 0.05$).

3.2. Qualitative Findings

After analyzing qualitative data through content analysis, 2 main themes were determined. These themes are: the effect of the augmented reality teaching material on the cognitive field and the effect of the augmented reality teaching material on the sensory field. Among these two main themes, the theme related to the affective domain is categorized as “efficiency” and “fun” sub-themes, and the theme related to the cognitive domain as “abstract/concrete” and “permanent learning” sub-themes.

Table 5: Students' views on the augmented reality implementation

Theme	***Comment***	***Participants***
Affective Domain (Efficient)	*This theme was created with the answers of the students who stated that they found the augmented reality implementation instructive, useful, successful and efficient.*	*P1, P3, P6, P8, P11, P15, P18, K20, P22 P25, P26, P29, P30*
Affective Domain (Fun)	*This theme was created with the answers of the students who stated that the augmented reality implementation was fun, remarkable, exciting and motivating.*	*P1, P3, P6, P9, P11 P15, P18, P24, P26, P29*
Cognitive Domain (Abstract/Concrete)	*This theme was created with the responses of the students who stated that the augmented reality implementation makes the subject more understandable by providing three-dimensional images and concretizing abstract concepts.*	*P2, P4, P9, P15, P22, P24*
Cognitive Domain (Meaningful learning)	*This theme was created with the answers of the students who stated that the learning realized with the help of the augmented reality implementation was more permanent.*	*P4, P12, P22, P26, P30*

As can be seen in the table, we can say that the most prominent themes are the "Efficiency" theme, which states that augmented reality implementations are useful, efficient and successful in the learning process, and the "Fun" theme, which indicates that the implementation is fun and interesting sub-themes of the Affective Field main theme. However, “Abstract/Concrete” and “Meaningful Learning” sub-themes of the Cognitive Domain, which explain the reason of these two themes and reveal that the

implementations of augmented reality make them more understandable by concretizing the difficult and at the same time abstract subjects, are also remarkable.

Figure 2. Example of AR implementations where two-dimensional pictures are seen in three dimensions

Theme of "efficiency - fun"

The experimental group students had the chance to observe the three-dimensional images of the organs that make up systems in our body, which they saw in two-dimensional textbooks before, with their mobile phones thanks to the AR implementation. Observing the systems of our body and the organs belonging to the systems in three dimensions instead of two dimensions allowed the students to see that an abstract concept became concrete and the learning process was facilitated. Figure 2 shows that students observe two-dimensional drawings in three dimensions. The opinion of Participant #15 on this issue is given below.

Participant #15: … Until today, I did not know exactly how the organs, whose two-dimensional pictures I have seen in the sources, are located in my body and what their real shapes look like. However, when we looked at the cards with our mobile phones in our science class, I felt and observed as if the organs were in our hands. Now I think I have learned the systems and organs in our body much better. It was so much fun that I will never forget this lesson.

Theme of "abstract/concrete and permanent learning"

It was observed that the participation of the students in the science learning activity with AR contributed to their meaningful learning of "Systems in Our Body Unit", which is an abstract subject. Students found themselves more successful in solving all questions

related to “Systems in Our Body Unit”, not only during the post-test implementation, but also in other tests they solved. This situation revealed that they can adapt what has been learned to other problem situations. The opinion of Participant #12 on this issue is given below.

Participant #12: … We saw the organs in three dimensions and learned by seeing which organs our systems consist of, and even had the opportunity to examine them as if they were touching. In this way, I can now easily answer questions about which organ belongs to which system.

Participant #22: … I am sure I have learned this unit very well. Thanks to this system implemented by our teacher, I followed the lesson better than ever.

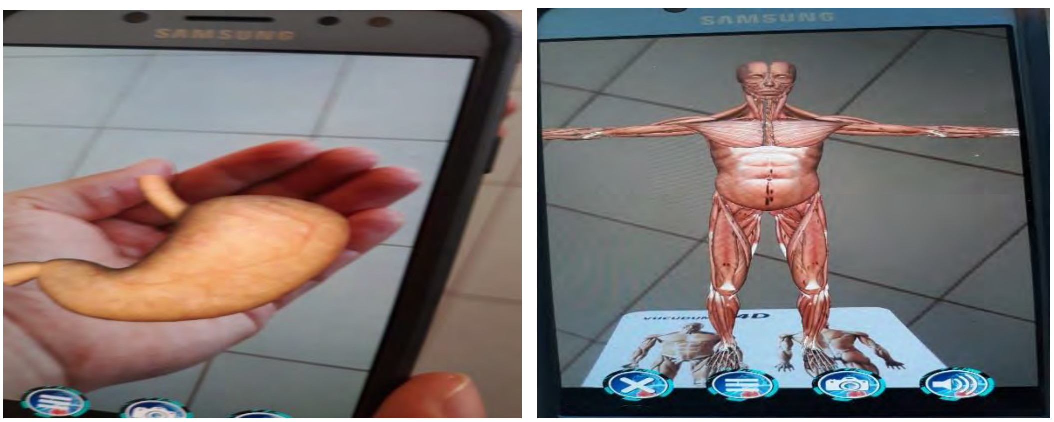

Figure 3. Samples showing students' interest in the AR implementation

In the light of these findings, it is possible to say that augmented reality implementations increase students' motivation and interest towards the lesson.

4. Discussion and Conclusions

The results of this research reveal that AR implementations increased the academic achievements of students. This result of the study coincides with the results of Sırakaya and Alsancak Sırakaya (2018) that the Augmented Reality implementations implemented to the students in the experimental group during the teaching process of the "Solar System and Beyond: Space Riddle" unit in the middle school science curriculum made a significant difference in terms of academic achievement compared to normal course materials. These results are also similar to the results of the study conducted by Perez-Lopez and Contero (2013) with the aim of teaching primary school students the subjects of digestive and circulatory systems and that indicates AR provides

permanent learning. In addition, it also supports the results of studies showing that students achieve the learning outcomes of the subject more successfully in a learning environment supported by AR implementations (Chen & Wang 2015; Enyedy et al., 2012; Hwang et al., 2016; Akçayır & Akçayır, 2017; İzgi Onbaşılı, 2018; Buluş, Kırıkkaya & Şentürk, 2019; Yıldırım, 2020).

Thanks to its ability to combine real and virtual environments, AR offers the opportunity to learn by doing and living, from astronomical events that cannot be observed in the classroom, to difficult chemical experiments. This research shows that AR implementations contribute to students' learning by concretizing abstract subjects. The result of the study coincides with the results of other studies showing that AR implementations contribute to the meaningful learning of abstract concepts by concretizing them (Perez-Lopez & Contero 2013; Shelton & Hedley, 2002; Shelton & Stevens, 2004; Tïmur & Özdemïr, 2018) and provide a more convenient teaching opportunity (Abdüsselam, 2014; İzgi Onbaşılı, 2018; Kamarainen et al., 2013; Núñez et al., 2008; Wu et al., 2013).

Another significant result of the study is that the interest and motivation of the students towards science education has increased along with the science teaching conducted with AR implementations. Thanks to AR implementations, it was observed that the students' interest in the lesson increased due to the remarkable fact that they saw the three-dimensional state of the objects, so they participated in the lesson more enthusiastically and learned the concepts they had difficulty learning more easily. Collaboration between student-teacher and student-student has developed since the students actively participating in the learning process are in constant interaction with each other and with their teachers during the implementation. Megahed's (2014) study shows that factors such as three-dimensional models, pictures, videos, animations that interactively improve students' perception and creativity facilitate learning. Recent studies show that augmented reality implementations are an effective course material used in learning environments (Akçayır & Akçayır, 2017; Buluş, Kırıkkaya & Şentürk, 2019; Chiang, Yang & Hwang, 2014; Korucu, Usta & Yavuzaslan, 2016; Yalçın Çelik, 2019). Studies conducted have shown that, similar to the results of this research, students are more eager, happier, more excited (Avcı & Taşdemir 2019; Chiang vd., 2014; Delello, 2014; Furió vd., 2015; İzgi Onbaşılı, 2018) and more active (Delello, 2014; Estapa & Nadolyn, 2015; Gopalan, Zulkifli ve Bakar, 2016) during the class in learning environments supported by AR implementations.

5. Suggestions

In the light of the results of this research, the following recommendations are presented to the researchers for their future research;

- Based on the result that AR affects students' motivation to learn science positively, science textbooks for science education can be designed in accordance with AR technology so that students can use these books to study at home.
- In-service trainings and courses can be organized for teachers on the preparation and use of AR implementations.
- This study conducted with middle school students can be repeated at different education levels so that the results can be compared.
- AR implementations can be used outside of the classroom environment with the help of mobile systems to be developed.

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