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Use of mixed reality applications in teaching of science

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Abstract
This study aims to investigate the effect of mixed reality applications on students' motivation to learn science. The study further aims to identify students' attitudes toward augmented reality applications and also intends to explore the students' views on mixed reality applications. A total of 42 primary school students participated in the study for a duration of 8 weeks. The results of the study indicate that mixed reality applications are effective in students' motivation for collaborative work in science teaching. In this context, it can be stated that mixed reality applications can make a significant contribution to the students' potential of collaboration with their peers. In the research, it was concluded that students were willing to use the augmented reality applications in science teaching and their anxiety levels decreased. The results obtained reveal that students are pleased to use augmented reality applications in science teaching. Qualitative data obtained from student views also support the quantitative results. The majority of the students stated that mixed reality applications should be employed in all courses and expressed that they are excited about the use of these applications and feel motivated for science teaching.

Keywords Augmented reality · primary education · virtual reality

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1 Introduction

In recent years, advances in technology have an important place in various other disciplines as well as educational sciences. Rapid change in technology affects education; the quality of both the students' learning and teachers' teaching experience intensify (Nincarean and Rahman 2013). The use of modern technology and tools in the learning and teaching process enables information to be transferred more easily and effectively (Raja and Nagasubramani 2018), changing the structure of traditional education, extending it beyond time and space and diversify the methods of teaching (Long et al. 2008). The modern educational technology, which changes the concept of traditional school, allows teachers to reposition themselves in their instructional practices and enables students to actively participate in the learning process by breaking their former roles as passive listeners (Lei 2017). With technology, teaching of knowledge and skills can also be facilitated in a traditional school environment (Courville 2011), the features of schools and classes can be altered with technological devices and networks. Laptops, tablet devices, and smartphones, which are seen as part of the teaching and learning process have become compulsory to utilise at many schools and they are employed particularly to facilitate students' learning (Eady and Lockyer 2013). New technologies, combined with advanced pedagogical tools and practices, create an innovative digital learning environment where collaborative work and interaction between students is possible and increase the efficiency of education (Kiryakova et al. 2018). Moreover, the integration of technology into the classroom develops students' collaborative learning skills, social skills, self-confidence, responsibility and skills to take initiatives (Ghavifekr and Rosdy 2015). Virtual reality and augmented reality, which attract students' interest in the lesson, increase their motivation for learning, develop their imagination and problem-solving skills, and positively affect their academic success, and pave the way for the foundations of education in the future (Kırıkkaya and Şentürk 2018; Yılmaz 2016; Hussein and Nätterdal 2015; Küçük et al. 2014). Virtual reality and augmented reality, which provide students with an exciting new educational reality, can be effectively used to teach science-based information (Huang et al. 2019).

Virtual reality and augmented reality that propose promising opportunities for new interactive applications; provide students the opportunity to learn, perform tasks and develop ways to interact with the world (Steffen et al. 2019). In addition, virtual reality and augmented reality aim to increase student knowledge to improve learning outcomes in education (Fernandez 2017). The use of augmented reality, defined as real worlds enriched with virtual objects, supports learning by providing physical interaction in learning environments (Erbaş and Demirer 2014), and offers educators opportunities to create authentic, student-centered, interactive learning experiences. Moreover, augmented reality engages students with complex problem solving and higher-order thinking skills for deeper learning (Wang et al. 2018). In a similar line, virtual reality provides students the opportunity to create their own knowledge from meaningful experiences and offers students the opportunity to explore solutions, actively participate in the process, develop empathy, improve creativity and collaborate with their peers through handling of authentic problems (Hu-Au and Lee 2017). Although both applications have common features, while augmented reality aims to increase reality by adding only virtual objects or information, virtual reality offers learners a real environment that gives them the feeling of being somewhere else (Fairén et al. 2017). Mixed reality, which is an attempt to combine the best features of both virtual reality and augmented reality, allows individuals to see the real, physical world and objects. Virtual reality, augmented reality and mixed reality can be explained as a combination of all the concepts has the possibility of developing and enhancing real life experiences (Brigham 2017).

The effectiveness of virtual reality and augmented reality has been analysed in terms of various variables in different fields such as speed reading (Rau et al. 2018), medical education (Bin et al. 2020), primary education (Robin de Lange and Lodewijk 2017), biology (Garcia-Bonete et al. 2018), higher education (Delello et al. 2015), mathematics and geometry education (Kaufmann 2009; Yingprayoon 2015; Voronina et al. 2019), and teacher education (Salmi et al. 2012). The literature review reveals studies that refer to virtual reality and augmented reality applications and discuss that both applications support collaborative learning (Jackson and Fagan 2000; Monahan et al. 2008; Pemberton and Winter 2009; Matcha and Rambli 2013). In this study, the motivation of students for learning science was discussed in terms of the variables of "research in science education, performance, communication, collaborative work and participating in science activities". Moreover, the study aims to identify the attitudes of students towards augmented reality applications. In this context, answers to the following questions were sought:

1. Is there a significant difference between the control group and the experimental group in their;

    1.1. motivation for research,
    1.2. motivation for their performance,
    1.3. motivation for communication,
    1.4. motivation ofr collaborative work,
    1.5. motivation for participation?

2. Is there a significant increase in the pre-test and post-test augmented reality attitude scores of experimental group students?
3. What are the feelings and thoughts of students about the use of mixed reality applications in science teaching?

2 Method

This study is designed with experimental design with a pretest-posttest control group. A total of 42 primary school students participated in the study which employed a mixed methodology. Primary school students in the 5th-grade are 11 years of age and they are all Cypriots. A total of 27 (64.3%) of the students are female and 15 (35.7%) of them are male. In the formation of the experimental and control groups, the participants were selected by random assignment and one was placed in one group and the other one was placed in the second group. Following this process, one of the groups was identified as the experimental group and the other as the control group through random assignment. Prior to the experiment, similarity levels of the groups were tested for both groups with a pre-test on dependent variables (See Table 1). In this context, 21 students were included in the experimental group and 21 students were included in the control group. Following the experimental process, post-test was administered to the experimental and control groups.

The data obtained from the pre-test applied to identify the motivation levels of the experimental group and the control group for science course were analysed with independent samples t-test. The values obtained were interpreted with a 0.05 significance level.

As Table 1 reveals, there is no significant difference between the experimental group and control group students' scores of motivation for research (t=.314, p>0.05), scores of motivation for performance (t=.196, p>0.05), scores of motivation for communication (t=1.495, p>0.05), scores of motivation for collaborative working (t=.263, p>0.05) and scores of motivation for participation (t=.262, p>0.05). In addition, no significant difference between the overall motivation levels of experiment and control groups was identified (t=.752, p>0.05). In this context, it can be stated that the motivation levels of the experimental group and the control group for science learning are homogeneous.

While the motivation levels of the experimental and control groups for science learning were obtained by the "*scale of motivation towards science learning*" the attitudes of the experimental group on which the augmented and virtual reality applications are used were identified through "*augmented reality applications attitude scale*". The views of the experimental group on mixed reality applications were collected by the semi-structured interview form.

2.1 Scale of motivation towards science learning

In order to identify the motivation levels of experiment and control groups for science learning, the scale of motivation towards science learning which was developed by Dede and Yaman (2008) was employed. Researchers (Dede and Yaman 2008), who

Table 1 Pre-test Motivation Levels of Experimental and Control Group Students

Dimensions of Motivation for Learning Science	Group	N	Mean	SD	$Sh_{\bar{x}}$	df	t	p
Motivation for research	Experimental	21	3.86	.670	.146	40	.314	.755
	Control	21	3.92	.638	.139			
Motivation for performance	Experimental	21	4.16	.602	.131	40	.196	.845
	Control	21	4.20	.654	.142			
Motivation for communication	Experimental	21	3.85	.797	.174	40	1.495	.143
	Control	21	4.20	.727	.158			
Motivation for collaborative working	Experimental	21	3.84	.867	.189	40	.263	.794
	Control	21	3.90	.567	.123			
Motivation for participation	Experimental	21	3.84	.867	.189	40	.262	.794
	Control	21	4.39	.680	.148			
Overall motivation score	Experimental	21	3.98	.567	.123	40	.752	.456
	Control	21	4.10	.461	.100			

emphasise the importance of motivation in lessons that are more difficult to understand, such as science and mathematics, developed the scale to identify the motivation levels of primary school students towards learning science. The five-point Likert type scale has 5 sub-dimensions; "Motivation for Research", "Motivation for Performance", "Motivation for Communication", "Motivation for Collaborative Work" and "Motivation for Participation" and consists of 23 items. For the scale which is scored from 5 to 1, it is presumed that the motivation levels of the students are high as their scores reach up to 5.00, and their motivation levels are low as their scores are closer to 1.00.

The Cronbach's Alpha reliability coefficient value for the whole scale was calculated as 0.80. Sample expressions for the sub-dimensions of the scale can be listed as follows: *Dimension of motivation for research:* “I would like to research more for the information that the teacher tells in the classroom”, “I like to explore the answers to science problems”. *Dimension of motivation for performance*: “I would like my teacher to appreciate my efforts in science class”, “I try very hard not to miss the important information our teacher tells”. *Motivation for communication*: “I like to help my classmates in science classes”, “I like to do group exercises with my friends in science classes”. *Motivation for collaborative work*: “I try to do my science homework in the best way I can”, “I ask my teacher to explain in detail while teaching the subject”. *Motivation for participation*: “I would like to put the best idea during class discussions", "I would like my friends to choose me to work while doing group work".

2.2 Augmented reality applications attitude scale

The study also aimed to identify the attitudes of the students towards augmented reality applications in the experimental group in which the mixed reality applications were used. In this context, augmented reality applications attitude scale developed by Küçük et al. (2014) was employed. The scale which has 3 sub-dimensions; “The use satisfaction”, “The use anxiety” and “The use willingness” consists of 15 items. The five-point Likert type scale is scored from 5 to 1. It is presumed that the attitudes of students reveal a positive increase as the scores reach up to 5.00 for the dimensions of the use satisfaction and the use willingness. The use anxiety dimension of the scale consists of negative statements and it is presumed that the levels of students’ anxiety decrease as their scores are closer to 1.00.

The Cronbach's Alpha reliability coefficient value for the whole scale was calculated as 0.83. Sample expressions for the sub-dimensions of the scale can be listed as follows: *The use satisfaction*: “I enjoy the lessons instructed with AR applications”, “Demonstration of 3D objects, videos, and animations on the book in AR applications increases my curiosity”. *The use anxiety*: “It is difficult to use AR applications”, “AR applications make my learning difficult because they confuse me”. *The use willingness*: “I want AR applications to be used in other lessons, as well”, “I want AR applications to take place in course books in the future”.

2.3 Semi-structured interview form

A semi-structured interview form was prepared by the researchers in order to identify the views of experimental group students on mixed reality applications. The semi-structured interview form was administered to the experimental group at the end of the experimental procedure. The form consisting of two questions was prepared to identify the students' feelings and thoughts about mixed reality applications. Interviews lasted for approximately 10-15 minutes. The qualitative data obtained from the interview form was analysed by content analysis method. The data was recorded with a voice recorder to prevent data loss. The data which was later transcribed by the researchers was divided into themes and categories, and frequency tables were created. In addition, direct quotations from students' expressions were included and themes and categories were supported. Mean, standard deviation, independent samples t-test and Mann Whitney-U analysis techniques were employed to analyse the quantitative data of the study.

2.4 Implementation

This study was designed in three stages: "planning, designing and reliability of the data obtained". The study was carried out by three researchers. The researchers first analysed the literature, focusing on the problem. Identifying the general objectives, the research questions were formed. After identifying the research problems and sub-problems of the research, the researchers selected the students to participate in the research. The researchers included students who had smart-phones in the experimental group. In addition, particular attention was paid to have an equal number of participants in the experimental and control groups, and to the similarity of both groups in terms of age, nationality, academic level and socio-economic characteristics. The researchers designated the data collection tools suitable for the problems and sub-problems, collected the data before and after the implementation, and correlated the data collection tools with the research problems and sub-problems. The researchers who collaborated during the collection, analysis and interpretation of qualitative and quantitative data, worked together in the reporting of the case study. The lessons conducted in the experimental and control groups were carried out by only one of the researchers with the students of the 5th grade of primary education. In this process, the other two researchers provided technical support to the researcher who conducted the trainings. The researcher, conducting the trainings, administered the data collection tools to the participants before and after the implementation and held face-to-face interviews with the students at the end of the application. The other two researchers took an active part in the analysis and interpretation of the data. Researchers produced alternative solutions according to the results obtained and made suggestions.

The 8-week study was carried out in a public school. While virtual reality and augmented reality applications were utilised for science teaching in the experimental group, a science teaching program including traditional methods was implemented in the control group. The study was limited to three units in science teaching: "my body", "human beings and environment / living creatures and life ", "the earth, the moon and the sun". In "my body" unit, topics such as foods and balanced nutrition, digestion of foods, our teeth and their roles, and excretory system in our body were covered. In the unit titled, "human beings and environment/living creatures and life", the purpose was to acquire the students with awareness about the environment by providing necessary knowledge about environmental problems. During the course, subjects such as destructive natural phenomena and ways of protection, earthquakes and volcanic eruptions were examined. "The earth, the moon and the sun" unit was also included in the curriculum. The unit, in which topics such as the earth and universe were discussed, targeted the comprehension of the basic properties of the earth and the moon, their landforms and structures, the rotational motion of the sun, and the earth and the moon's relative movements. Science education is an education that provides students with the opportunity to research by developing their feelings of curiosity, prepares the ground for them to discover similarities and differences by observing incidents and entities, and is effective in acquiring the students with the skills that are essential in daily life (Simsar and Doğan 2019).

Lessons for science education are planned 3 days a week and each lesson is 40 minutes. In the control group, while the researcher conducted the lessons with direct

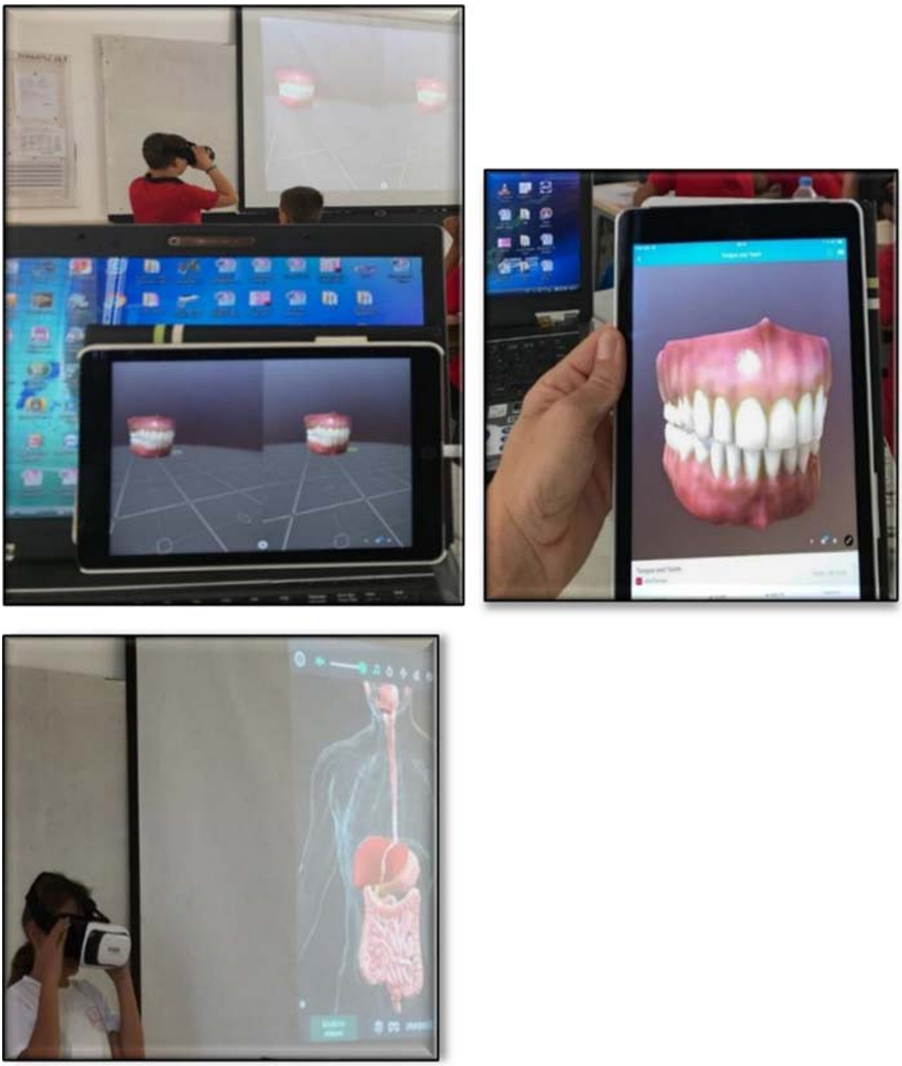

Fig. 1 Virtual Reality Applications (Subject studies: My body)

instruction and question and answer teaching methods, in the experimental group the lessons were supported with virtual reality and augmented reality applications. At the beginning of the study, a one-hour informative training on the use of virtual reality and augmented reality applications was also delivered to the experimental group students by the researchers. While the traditional textbooks approved by the Ministry of Education are utilised in the control group, the researchers preferred to use ready-made applications for virtual and augmented reality activities. Attention has been paid to ensure that the preferred applications are appropriate for the content of the science course and the age level of the students. Virtual reality application is a paid one designed by Tamayo (2018) which is named Gums, Teeth and Tongue and the 3D image is used in this application (https://www.alexandertamayo.com/projects/zV8ad). Gums Teeth and Tongue 3D image is visualised in Google Play Store using sketch fab application (https://sketchfab.com/3d-models/tongue-and-teeth-8e5b1da6c2a34670b7fbb0e73a97018b). Likewise, access was provided to the content in the human body educational VR 3D with the mosaic3D application available at Google Play Store (https://play.google.com/store/apps/details?id=com.rendernet.humanmale). The researchers preferred to utilise this application which is compatible with all devices since the 3D images were designed according to the age level of the students. There are also books designed with augmented reality among the tools used in the experimental group (Ganeri 2014; Banqueri 2016). The augmented reality images included in the iStormAR book designed by Ganeri (2014) are enabled with the iStormAR application, which is available to download for free on Google Play Store. (https://play.google.com/store/apps/details?id=com.redfrog.istorm&hl=en). Virtual reality and augmented reality applications used in the experimental group are demonstrated in Figures 1 and 2.

While the activities in the control group are carried out using traditional methods in real environments, in the experimental group, technological materials are integrated into the learning environments. In the experimental group, where modern technologies are integrated into learning environments, the researcher in the role of a teacher assumed the role of a guide and supported science subjects with virtual reality and augmented reality applications. The aim for the experimental group in which laptop, projector, smartphones and VR glasses among the wearable technological tools are utilised, is to It is aimed to contribute to students' learning with the help of 3D virtual environments. Both in the experimental and control group, students carried out

Fig. 2 Augmented Reality Applications (Subject studies: The earth, the moon and the sun / Human beings and environment)

collaborative work and individual activities with their group friends. In addition, activities in both groups were carried out in a classroom setting. However, in order to realise the virtual reality and augmented reality applications in the classroom environment, the researchers paid attention to the level of light in the classroom and ensured the availability of 3G network in the classroom for smooth implementation of the applications. With this study, researchers aimed to show that virtual reality and augmented reality applications can be performed effectively not only in the laboratory environment but also in a well-designed classroom environment.

3 Results

The findings obtained from quantitative and qualitative data in line with the objectives of the study are presented below.

3.1 The findings on the motivation levels of experimental and control group students towards learning science

The Mann Whitney-U Test was used to determine the post-test motivation scores of the control group in which a traditional method was employed and the experimental group in which augmented and virtual reality applications were employed. Table 2 reveals students' post-test motivation scores for science learning and post-test scores for the sub-dimensions of motivation for research, motivation for performance, motivation for communication, motivation for collaborative work, and motivation for participation.

When the motivation scores of the experimental group in which the mixed reality applications were employed and control groups in which a traditional method was employed are analysed, it is revealed that while there is no significant difference between the pre-test motivation scores (See Table 1), there is a significant difference

Table 2 Findings on the Post-Test Motivation scores of Experimental and Control Groups towards Learning Science

Dimensions of Motivation for Learning Science	Group	N	$\bar{x}_{sira}$	$\sum_{sira}$	U	z	P
Motivation for research	Experimental	21	20.93	439.50	208.500	-.304	.761
	Control	21	22.07	463.50			
Motivation for performance	Experimental	21	20.93	439.50	166.500	-1.373	.170
	Control	21	22.07	397.50			
Motivation for communication	Experimental	21	19.31	405.50	174.500	-1.170	.242
	Control	21	23.69	497.50			
Motivation for collaborative working	Experimental	21	25.24	530.00	142.000	-2.019	.044
	Control	21	17.76	373.00			
Motivation for participation	Experimental	21	23.86	501.00	171.000	-1.328	.184
	Control	21	19.14	402.00			
Overall motivation score	Experimental	21	23.17	486.50	185.500	-.882	.378
	Control	21	19.83	416.50			

between the post-test motivation scores only in the dimension of motivation for collaborative working (U=142.000, p<0.05). As Table 2 reveals there is no significant difference between the overall motivation scores of experimental and control group students' motivation towards learning science (U =185.500, p>0.05), and the post-test scores of motivation for research (U =208.500, p>0.05), motivation for performance (U=166.500, p>0.05) motivation for communication (U =174.500, p>0.05) and motivation for participation (U =171.000, p>0.05). In this context, it can be stated that mixed reality applications are particularly effective in collaborative working and they contribute positively to students' willingness for collaborative work in the process of learning science.

3.2 The attitudes of experimental group towards augmented reality applications

The paired sample t-test analysis technique was used to determine the attitudes of the experimental group towards the augmented reality applications implemented during science classes. Table 3 reveals the scores of students for their satisfaction, anxiety and willingness to the use of augmented reality applications.

As Table 3 reveals there is no significant difference (t=-.981, p>05) between the pre-test (M=4.10, sd=.693) and post-test (M=4.31, sd=.526) scores for the use satisfaction for augmented reality applications during the science courses. This reveals that students are pleased to use augmented reality applications before the experimental process. When the students' levels of use anxiety for augmented reality applications are analysed, it is revealed that the there is a significant decrease in favour of post-test anxiety levels (t=9.440, p<.05) when pre-test anxiety levels (M=3.12, sd=.769) and post-test anxiety levels (M=1.38, sd=.333) are compared. The findings suggest that although students were satisfied with the use of augmented reality applications in science teaching, they still felt moderate anxiety before the experimental procedure. However, at the end of the experimental procedure, it was determined that there was a positive decrease in the anxiety levels related to the applications of augmented reality. Moreover when the students' willingness to use augmented reality applications during the classes are analysed, it is revealed that there is a significant difference in favour of post-test scores (t=-3.535, p<.05) in the pre-test (M=3.69, sd=1.19) and post-test scores

Table 3 Pre-Test and Post-Test Augmented Reality Applications Attitude Scores of Experimental Group Students

Dimensions of AR	Experimental Group	N	Mean	SD	$Sh_{\bar{x}}$	df	t	P
The use satisfaction for AR applications	Pre-Test	21	4.10	.693	.151	20	-.981	.338
	Post-Test	21	4.31	.526	.114			
The use anxiety for AR applications	Pre-Test	21	3.12	.769	.167	20	9.440	.000
	Post-Test	21	1.38	.333	.072			
The use willingness for AR applications	Pre-Test	21	3.69	1.19	.261	20	-3.535	.002
	Post-Test	21	4.71	.435	.094			

(M=4.71, sd=.435). The results of the study reveal that students are willing to use augmented reality applications and have positive attitudes towards these applications.

3.3 The views of the experimental group students towards the implementation

Following the implementation period that lasted for 8 weeks, face to face interviews were conducted in order to identify the feelings and thoughts of the students in the experimental group. Through the semi-structured interview form prepared by the researchers, the students' views about the science course in which mixed reality applications are used together are determined. In order to identify the views of students the following two questions were asked: "Would you like to use the mixed reality applications that you have used during the science course in other courses as well?" and "How did you feel yourself while using the mixed reality applications during the science course?" The qualitative data obtained from the views of the students are presented below.

As seen in Table 4, a large majority of students reflect positive views on the use of mixed reality applications in other courses. While a total of 13 students stated that they would like mixed reality applications to be used not only in science courses but in all courses, five students stated that they should be used in social sciences courses and two students stated that they should be used only in the science course. One student stated that he/she would not want mixed reality applications to be used in other courses:

> (S8): "I would like them to be used in other courses than the science course"
> (S14): "I would like mixed reality applications to be used in the science course"
> (S3): "I would like mixed reality applications to be used in every course"
> (S21): "I believe mixed reality applications are more effective in science course. So I would like them to be used in science courses"

Only one student stated that he/she would not want mixed reality applications to be used in any of the courses:

> (S19): "I wouldn't like to use them in other courses".

The data obtained from the research reveals that the majority of students are satisfied with the implementation of mixed reality applications in science courses. One student has expressed an opinion on not using mixed reality applications in courses. In this

Table 4 The Student Views on the Use of Mixed Reality Applications in Other Courses

Themes	Codes	f
The willingness to use mixed reality applications	It should be used in all the courses	13
	Social sciences course	5
	Only in the science course	2
The reluctance to use mixed reality applications	It should not be used in any of the courses	1

context, it is thought that the main reason why this student has negative views on mixed reality applications is the possibility that he/she feels anxiety towards technology.

Following the implementation period that lasted for 8 weeks the question; “How did you feel yourself while using the mixed reality applications during the science course?” was directed to the experimental group in which mixed reality applications are used together. The answers of the students to this question are presented in Table 5.

The qualitative data obtained from the study revealed that the majority of the students were excited to use the applications (n=8). Students who felt motivated towards the lesson (n = 6) stated that they felt joyful, entertained and acquired interesting learning experiences during the implementation (n=2). Although the majority of students have positive emotions for virtual and augmented reality applications, it is also revealed that 2 students find applications ordinary:

> (S2): “Seeing many organs in Our Body unit in a realistic way rather than in pictures made the lesson more fun”
> (S5): “I was extremely excited to use applications”
> (S7): “The course was very nice and fun”
> (S16): “Learning the subjects in a different environment apart from the textbook attracted more of my attention to the subject”
> (S17): “I can see a transparent void and our bodies in this space. I had a different learning experience”
> (S19): “It was an ordinary lesson for me”

Findings from the research show that students are satisfied with the mixed reality applications used in science course in general.

4 Discussion and conclusion

In this research, the effect of mixed reality applications used in science teaching on students' motivation to learn science is discussed. The results of the study revealed that while mixed reality applications did not make a significant difference in the motivation levels of students for research, performance, communication, participation and learning

Table 5 The Feelings and Thoughts of the Students about the Use of Mixed Reality Applications in Science Course

Themes	Codes	f
The feelings on the use of mixed reality applications	Excited	8
	Motivated	6
	Joyful	5
	Realistic	2
	Entertained	2
	Interested	2
	Ordinary	2

science in general, they revealed a significant difference in their motivation towards collaborative work in science learning. In the study of Sarıkaya and Sarıkaya (2018), it was concluded that the use of augmented reality increased the motivation of students to learn science, whereas this study concludes that mixed reality applications were found to be effective in the students' motivation for collaborative working. Alhumaidan et al. (2018), in their study, demonstrated that augmented reality supports collaboration when used in different contexts. Collaborative learning, which is stated to be effective in primary school settings and provides students the opportunity to participate in joint activities that support the learning process, is perceived as important in developing students' communication, team working and problem-solving skills (Leeuwen and Janssen 2019; Thurston et al. 2019; Munir et al. 2018). In a similar line, Bistaman et al. (2018) state that the augmented reality system positively influences the overall class collaboration, and that augmented reality applications are adopted by primary school students and teachers. Researchers (Bistaman et al. 2018) emphasise that augmented reality system will increase the interaction, motivation and cooperation between teachers and students. Rahman et al. (2014) state that the virtual world is adopted as a significant tool particularly for collaborative learning in modern educational practices and that the virtual world is a great application for online collaborative learning and has a wide potential. When the benefits of collaborative learning for students are taken into consideration, the findings obtained from this study gain meaning and the use of mixed reality applications is recommended to increase the students' motivation for collaborative work.

The results obtained from the research revealed that the augmented reality applications used in science teaching did not make a significant difference in the satisfaction of using the applications, but it was found to be effective on the willingness and anxiety for using the applications. In the study, it was concluded that there was no significant difference between the pre-test and post-test satisfaction levels for the use of augmented reality applications. It can be stated that students' satisfaction levels are already high due to the fact that students will use a different application than traditional methods in science teaching, and as a result, there is no significant difference in post-test satisfaction levels. It is concluded that the students' willingness to use augmented reality applications increased significantly at the end of the implementation period, while anxiety levels for the applications decreased in a positive way. It is also determined that the students' attitudes to use augmented reality applications increased positively while their anxiety levels for the applications decreased in a positive way. Similarly, Sarıkaya and Sarıkaya (2018) also concluded that augmented reality applications changed students' attitudes towards learning science positively. Moreover, the research conducted in relation to this shows that students have positive attitudes towards augmented reality applications (Sarıkaya and Çakmak 2018; Atasoy et al. 2017).

The majority of the students stated that they wanted mixed reality applications to be used not only in science teaching but also in other courses. While some of the students stated that they wanted mixed reality applications to be used particularly in social studies courses, some of them stated that these applications were suitable for science course. The results reveal that students are pleased with the use of mixed reality applications. The research has shown that students are excited when using mixed reality applications and are motivated for science teaching. Saltan and Arslan (2017) state that there are studies that provide evidence that educational environments that are enriched with augmented reality applications increase motivation and satisfaction of learners. The findings of Saltan and Arslan (2017) support the results of this study. In addition, the experimental group students participated in the research expressed that the applications were fun to use and that they performed interesting activities. Yılmaz and Göktaş (2018) indicated that augmented reality applications provide benefits such as enabling learning through entertainment and enhancing students' attention and motivation. Ozdamli and Hursen (2017) in their study they conducted with prospective teachers stated that prospective teachers have positive views and suggestions about augmented reality applications. Based on the findings obtained, it can be stated that mixed reality applications are effective throughout different levels of teaching. In this study, it is determined that the use of mixed reality applications in science teaching provides students with various advantages. In this context, it is recommended to implement mixed reality applications in different courses and to discuss their effects according to various variables. In addition, technology integration should be emphasised in curriculum development studies, and the effectiveness of the curriculum should be tested, particularly by integrating mixed reality applications into the curriculum.

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