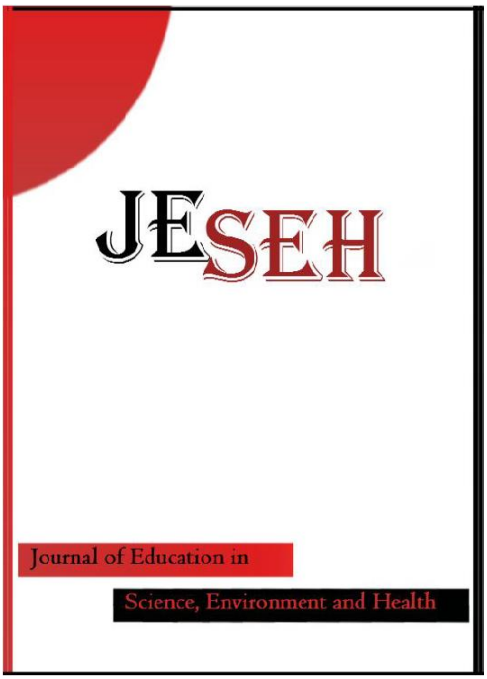

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The Effect of Augmented Reality Applications in Biology Lesson on Academic Achievement and Motivation

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Abstract

In this study, it was aimed to determine the effect of activities based on augmented reality applications in 9th grade biology lesson on students' achievement and motivation towards biology lesson and to get students' opinions about the applications. In the study, mixed method was used. The study group of the research consisted of students of two different classes at the 9th grade level of a private high school located in the city center of Karaman in the 2018-2019 academic year. When the research findings were examined, it was seen that the academic achievement post-test mean scores of the experimental group students were found to be significantly higher than the mean scores of the control group students. According to another finding of the study, there was no significant difference between the experimental group and the control group students in terms of the total mean scores obtained from the motivation questionnaire for biology lesson. However, a significant difference was found in favor of the experimental group in terms of "anxiety in exams" dimension. As a result of the research, the students stated that they liked the biology lessons in which augmented reality applications were carried out, that augmented reality applications made abstract concepts concrete and made them more permanent, and that the lessons conducted in this way were fun.

Introduction

Today, there is a need to train individuals who can acquire increasingly complex knowledge and skills and keep up with the rapid change of this information. In addition to the rapid increase in knowledge, since 21st century skills are technology-oriented, the question of how information technologies can be used to support and enrich education, has led studies in the field of education and educational technology in recent years (Kozma & Anderson, 2002; Wang & Hannafin, 2005; Watson, 2001). In addition to these, it is thought that current curricula are insufficient to respond to the differing expectations of today's youth, which is called the digital generation or generation z. 21st century students, called digital natives, differ from previous generations due to their distinctive features such as their desire to access information very quickly, games instead of serious studies, visual and graphic elements instead of long texts, having a parallel cognitive structure, and being able to do more than one job simultaneously (Bilgiç et al.,, 2011). These innate features of digital natives have also led to innovations in the world of education and a new learning culture has emerged. In this sense, while teaching processes are being structured, new technological approaches have started to be preferred. For these reasons, it has become imperative to know the characteristics of the new generation and to configure the education-teaching process with teaching methods suitable for their characteristics, reshape curricula and environments to allow the use of innovative technologies (Somyürek, 2014; İzgi Onbaşılı, 2018).

Considering the developmental periods, the emergence of computers first, then the internet, and then the development and spread of mobile devices, and the growing technological transformation had important reflections on education and training environments (Hayes et al., 2004). Printed materials, which make learning more tangible and permanent, but have controversial dimensions in terms of cost, portability, usability and accessibility, have begun to move to digital media in recent years (Smaldino et al., 2019). Now, it has become inevitable to use digital tools and materials as materials in addition to teaching lessons with more than one teaching method (Seferoğlu, 2006). Integrating education with new technologies has allowed teachers to transform learning materials consisting of fixed text and graphics into more interactive multimedia materials (Huang et al., 2016). With the widespread use of the internet in the digital environment, hypermedia (video, sound, animation, picture, etc.) and web 2.0 tools have begun to be used more in learning and teaching environments (Andersen, 2007; Greenhow et al., 2009). Today, in addition to these technological tools, new

applications are developed through mobile and wearable technologies and used in learning environments. One of these innovative digital technologies used is Augmented Reality technology.

Augmented Reality

Augmented Reality (AR) technology, which was developed in the 1960s, inspired by the work of Ivan Sutherland and his students at Harvard and Utah universities on computer graphics, came into existence fully in the 1970s. While it was officially first used by the United States Air Force and NASA, this technology became widespread after the 1990s and reached wider masses (Feiner, 2002). According to Azuma (1997), AR is a virtuality-based technology that enables us to interact with the real world in real time. According to Cabero and Barroso (2016), AR is a technology that allows the user to see the real world by combining real elements with virtual attachments. In other words, AR is a virtual reality application in which users interact with virtual objects while interacting with the real world without affecting the real world (Zhu et al., 2004). It is the creation of an interactive environment between the virtual world and the real world that can accommodate the characteristics of both environments. AR technology is used to create this interactive environment (Bronack, 2011; Klopfer & Squire, 2008). In other words, AR enriches the existing reality with virtual objects it adds to the real environment and makes it more dynamic (Cheng & Tsai, 2013; Kerawalla et al., 2006). AR provides a seamless interface and natural interaction for users by combining the real and virtual worlds (Cai et al., 2014; Kaufmann, 2003; Matcha & Rambli, 2013). Azuma (1997) lists the characteristic features of AR technology as follows in his study to determine the limits of AR technology:

- Combines the real with the virtual,
- It is real-time interactive,
- It is 4 dimensional.

AR technology is the placement of four different elements in the real world in three dimensions: the camera, the computer infrastructure, a marker and the real world. AR is a technology based on the appearance of a four-dimensional object designed on the target picture, output or materials determined by a developer and creating the effect of the object being on the target picture, output or material (Augment, 2020). In addition to being used in various fields such as AR technology, science, industry, trade, health, space and aviation, it has recently had an important and widespread use in the field of education.

Use of Augmented Reality in Education

The development in technology has transformed AR from a technology that only works with special equipment, to a technology that can be easily used on personal computers or mobile devices. Today, it is seen that AR is used in many different sectors such as tourism, military, health, advertising and education (Buluş Kırıkkaya & Şentürk, 2018; Gümüş & Boydaş, 2021; İçten & Bal, 2017; İzgi Onbaşılı, 2018; Yen et al., 2013). Especially the widespread use of mobile devices has paved the way for the use of AR in educational environments (Wu et al., 2013). In the reports of institutions and organizations that direct educational technologies in the international context, it is predicted that AR is among the potential technologies at the K-12 and university level, and that it can make a remarkable contribution to learning with its immersive and developable structure in the future (Johnson, et al., 2014; Johnson. et al., 2016).

AR technology is used in teaching inaccessible or invisible objects in educational environments, in the application of dangerous experiments, and in embodying abstract concepts. In addition, it is known that it has advantages for cognitive and affective development such as increasing permanence in learning, making lessons more enjoyable, and increasing students' interest (Lee, 2012; Wu et al., 2013). At the middle and high school level, science is one of the fields that students have difficulty in (Timur & Özdemir, 2018). The reason for this is suggested that science subjects are rich in abstract concepts. In order to understand abstract scientific concepts, students need to construct mental models (Ibáñez et al., 2014). AR makes it possible to teach situations that cannot be observed in the classroom environment by combining real and virtual (Kerawalla et al., 2006; Shelton & Hedley, 2002). Thus, science subjects that cannot be observed in real life can be taught by doing and experiencing. In addition, AR enables abstract concepts to be learned more easily by concretizing them (Abdüsselam, 2014; Kamarainen et al., 2013; Núñez et al., 2008; Shelton & Hedley, 2002; Shelton & Stevens, 2004; Wu et al., 2013). The use of AR applications has become even more important, especially in the teaching of applied sciences, where the use of technological tools and equipment such as mathematics and science are

more needed; As the idea that AR can be used in educational environments has become widespread, many applications that can be used in science education have been designed recently.

The field of science is of great importance in the development of countries. However there are still problems related to the learning-teaching process in Turkey, such as the lack of integration of learning materials and technology in science education, and the predominance of teacher-centered methods in teaching. It is thought that the fact that students' science achievement is not at the desired level in the national and international context may be related to these problems (Fidan & Tuncel, 2018; Ültay & Ültay, 2020). The fact that AR provides the opportunity to have real world assets and objects in digital environments in the same environment (Azuma et al., 2001) adds some exciting features to the learning of students learning in traditional learning environments. In addition, thanks to AR, some features that cannot be seen in the real world can be modeled three-dimensionally and numerically, and this information can be presented together with real world assets, allowing some abstract concepts to be concretized (Timur & Özdemir, 2018), it increases academic success by transforming the learning process from abstract to concrete, especially in teaching science subjects (Abdüsselam & Karal, 2012).

Research in recent years indicates that AR makes many contributions to educational environments. It is among the results obtained in studies that the use of AR increases academic achievement, supports learning by doing and experiencing and learning by questioning, increases class participation and motivation, makes lessons more enjoyable, facilitates concept teaching and reduces misconceptions (Abdüsselam, 2014; Bressler & Bodzin, 2013; Cai et al., 2014; Chiang et al., 2014; Chen & Wang, 2015; Enyedy et al., 2012; Furió et al., 2015; Hsiao et al., 2012; Hwang et al., 2016; Ibáñez et al., 2014; Kerawalla et al., 2006; Lin et al., 2013; Matcha & Rambli, 2013; Perez-Lopez & Contero, 2013; Rosenbaum et al., 2006; Sırakaya, 2015; Singhal et al., 2012; Shelton & Hedley, 2002; Solak & Cakir, 2015; Squire & Jan, 2007; Tian et al., 2014; Vilkoniene, 2009; Wang et al., 2014; Zhang et al., 2014).

Like cognitive factors, affective factors also play an important role in students' achievement (Tuan et al., 2005). Motivation, which is among these affective factors, is defined as the initiation of the necessary process to meet a need (Waterman, 2005). It is known that motivation is a factor that plays an important role in the learning process and that highly motivated students participate more in the lesson (Dede & Yaman, 2008; Wolters & Rosenthal, 2000). In this context, AR may contribute to the positive development of students' attitudes and motivations towards learning with its features. Today, the use of technology to increase the desire to learn has become a very popular research topic (Di Serio et al., 2013). The fact that this research investigates the effect of AR applications on motivation as well as the effect of academic achievement and at the same time including student opinions makes the research important in terms of contributing to the field. Greene (2007) defined the mixed method as "more than one way of seeing". In this study, it was considered important to determine the academic success and motivation levels of the students, as well as their experiences and opinions about the practice, which were determined quantitatively. In addition, when we look at AR studies in education, it can be said that most of them are at secondary school level and there are relatively few studies at high school level. However, high school students love to learn by exploring and having fun, they prefer fast access to information, thus using technology while researching and learning, they prefer graphics over texts. It is mentioned that the increasing use of augmented reality technologies in educational environments is due to some unique characteristics of young individuals. Kapil and Roy (2014) defined the digital generation as individuals who want a technology-oriented life, are productive social media users, live in a communication environment equipped with advanced technologies, and can actively use technology to overcome the problems they encounter. In order for individuals with these characteristics to participate actively in their learning processes and to increase their interest and gain effective permanent learning experiences, multimedia materials should be created for them and used in teaching environments (Wang et al., 2013).

Based on the idea that technology-based approaches can be useful in different school levels and in different courses, in this study, it was aimed to determine the effects of activities based on AR applications on the ninth grade biology lesson "cell" unit "cellular structures and their functions" subject on the academic achievement of students and their motivation for the biology lesson, and to get students' opinions on the applications carried out. The subject of the 9th grade cell unit "cellular structures and their functions" includes sub-headings such as parts of prokaryotic cells, the structure of eukaryotic cells and the parts that make up this structure, the functions that organelles take in the cell, different cell examples, and intracellular organization. These subjects and concepts are quite abstract and it is important to teach them concretely through various visuals, three-dimensional models, videos and simulations. In addition in the Biology curriculum of the Ministry of National Education, while comparing different cell samples visual elements (photos, pictures, drawings, cartoons, etc.), graphic organizers (concept maps, mind maps, diagrams, etc.), e-learning objects and applications (animation, video, simulation, infographic, augmented and virtual reality applications, etc.) is recommended. Considering all these,

it is thought that AR applications will be an effective way to teach the subject of "cellular structures and functions" of the cell unit.

The hypotheses of the experimental research carried out in this direction are presented below:

1. The posttest point averages of the experimental group in which the activities based on AR applications were applied were significantly higher than the posttest point averages of the control group in which the activities based on the current program were applied.
2. The motivation score averages of the experimental group in which the activities based on AR applications were applied were significantly higher than the motivation point averages of the control group in which the activities based on the current program were applied.

The sub-problem regarding the qualitative dimension of the research is given below:

- What are the opinions of the experimental group students about the AR activities applied within the scope of the research?

Method

Research Design

The design of the research is the explanatory sequential mixed design. The purpose of this design is to use qualitative data to explain quantitative findings in more detail. The first stage in this process includes the collection of quantitative data and the analysis of the data. Afterwards, it is aimed to help explain the answers given in the quantitative dimension with the interviews made at the qualitative stage (Creswell, 2014). The explanatory design is probably the most understandable of the mixed method designs (Creswell & Plano Clark, 2011). One of the reasons for choosing this design is that the researcher and the main problem of the research are quantitative oriented. In addition, its two-stage structure makes this design easy to apply (Creswell & Plano Clark, 2011). The researcher preferred this design in order to carry out the two methods in separate stages, to collect only one type of data at a time, and to support the quantitative data using qualitative data and to explain it in more depth and detail. The static-group pretest-posttest design was applied in the quantitative dimension of the study. In this design, the experimental group and the control group are selected without random assignment. Pretest and posttest are applied to both groups. Experimental process is done only to the experimental group (Cresswell, 2014). While experimental studies are carried out with students in schools, it is often possible to work with ready-made groups. It is generally not possible to make changes in groups and to perform random assignment. In this research, it was necessary to work with previously formed groups, since the experimental study was started in the middle of the academic term. However the experimental and control groups were randomly assigned from these groups. The case study was applied in the qualitative dimension of the study. The case study delves into and analyzes the factors that explain the current situation or influence change and development (Best & Kahn, 2014). With the case study design, the researcher aimed to facilitate the explanation and understanding of the possible change in the scores obtained from the academic achievement test and motivation questionnaire before and after the experimental application. In the context of the case study, the interview method was used to collect the qualitative data of the research. The purpose of the interview is to learn what is in the mind of the individual and to reach his point of view (Patton, 1990). Interviews are used to obtain information about the knowledge and experiences of the individual (Best & Kahn, 2014). Interviews allow to obtain information about what cannot be seen directly and to make alternative explanations about what is seen (Glesne, 2016). In this study, this method was used to obtain the experiences, opinions and suggestions of the participants regarding the experimental process. Within the scope of the research, it was aimed to reach a rich and a variety of data that can confirm each other by employing more than one data collection method.

Study Group

The students of two different classes, who were studying at the ninth grade level of a private high school in Karaman, were the study groups of the research. One of these groups was determined randomly as the experimental group and the other as the control group. The experimental group consisted of 17 students and the control group consisted of 21 students. The average age of both groups is 15. Students in both the experimental and control groups do not have any knowledge or experience of AR applications. While determining the study group of the experimental research, previously formed ready groups were used. Considering the qualitative

dimension of the research, this method can be expressed as easily accessible case sampling. Easily accessible case sampling is often used when the researcher is not able to use other sampling methods. This sampling method brings speed and practicality to the research (Yıldırım & Şimşek, 2018). It was envisaged that the students in the experimental group of the research would be the participants of the qualitative dimension of the research. It was envisaged that the students in the experimental group of the research would be the participants of the qualitative dimension of the research. However, the researcher ended the data collection process at the point where the concepts and processes that emerged while the interview data were collected and analyzed began to repeat each other. At this stage, interviews were conducted with 11 participants. These participants participated in the interviews voluntarily.

In order to determine whether the experimental and control group students were equivalent in terms of academic achievement levels in the biology course cell unit, the independent samples t test was applied to determine whether there was a significant difference between the academic achievement pretest score averages. The t test results of the students' pretest mean scores according to the group are shown in Table 1.

Table 1. The *t* test results of the students' academic achievement pretest mean scores according to the group

Group	n	x̄	Sd	df	*t*	*p*
Experiment	17	10.24	2.71	36	0.757	0.415
Control	21	11.00	3.38			

p≤.05.

When Table 1 is examined, it is seen that there is no significant difference between the academic achievement pretest mean scores of the experimental and control group students ($t_{(36)=}0.757$, p≤0.05). Based on this finding, it can be said that the experimental and control group students are equivalent in terms of academic achievement pretest mean scores in the biology course cell unit. In order to determine whether the experimental and control group students were equal in terms of their motivation levels for the biology lesson, the independent samples *t* test was applied to determine whether there was a significant difference between the motivation questionnaire pretest score averages. The *t* test results of the students' motivation pretest mean scores according to the group are shown in Table 2.

Table 2. The *t* test results of the students' motivation pretest mean scores according to the group

Factor	Group	n	x̄	Sd	df	*t*	*p*
Intrinsic motivation	Experiment	17	20.18	2.94	36	0.585	0.413
	Control	21	19.05	4.96			
Extrinsic motivation	Experiment	17	21.12	3.02	36	0.457	0.470
	Control	21	20.33	3.50			
Interest in learning	Experiment	17	19.29	3.67	36	1.748	0.091
	Control	21	16.76	5.03			
Responsibility for learning	Experiment	17	20.12	3.24	36	1.628	0.482
	Control	21	19.19	4.51			
Confidence in learning	Experiment	17	19.47	4.93	36	1.134	0.264
	Control	21	17.62	5.06			
Anxiety in exams	Experiment	17	16.18	4.71	36	1.084	0.286
	Control	21	17.71	4.04			
Total	Experiment	17	116.35	12.10	36	0.919	0.364
	Control	21	110.67	23,03			

p≤..05.

When Table 2 is examined, it is seen that there is no significant difference between the motivation pretest mean scores of the experimental and control group students in terms of total motivation level and in terms of each sub-dimension ($t_{(36)=}0.919$, p≤0.05). Based on this finding, it can be said that the experimental and control group students are equivalent in terms of their motivation pretest mean scores.

Data Collection Tools

The experimental design of the research is the static group pretest-posttest design, and an achievement test consisting of 43 questions was developed by the researcher to be applied to the experimental and control groups as pretest and posttest. While creating the items for the test, cooperation was made with biology experts and language experts, the relevant literature was scanned to ensure content validity, and opinions were received from

three experts working in the relevant field. As a result of expert evaluations, corrections were made on the test and the agreement value between the evaluations of the experts was calculated (Miles & Huberman, 1994); It was determined as 0.81. The test was applied to students studying in two different high schools in the city of Karaman in order to calculate its reliability. The reliability of the test as a result of the application was calculated by the Kuder-Richardson (KR-20) method as r=0.95. Item difficulties (pj) were determined based on the data obtained from the pre-application and the average difficulty of the test was calculated as 0.44. Accordingly, it is possible to say that the developed test is a medium difficulty test. In the study, item discrimination values were calculated. As a result of the obtained values, item 9 (pj=0.36, qj=0.64, rjx= 0.26) and item 17 (pj=0.53, qj= 0.47, rjx=0.29) were not included in the final test due to their low efficacy. After these changes, 41 questions remained in the test. After the changes, the reliability of the test was recalculated with the KR-20 method and the reliability coefficient was found to be r=0.95. The high values of this coefficient, close to 1.00, indicate that reliability in terms of internal consistency is provided (Demirel, 2008). This value is quite good for an achievement test.

In order to determine the effect of AR applications on the motivation of students towards biology lesson, "Motivation Questionnaire for Biology Lesson" (BDME), which was developed by Glynn and Koballa (2006) and adapted into Turkish by Ekici (2009), was used. The original questionnaire developed by Glynn and Koballa (2006) consists of six dimensions. These are *intrinsic motivation, extrinsic motivation, interest in learning biology, responsibility in learning biology, confidence in learning biology, and anxiety in biology exams*. It is stated that the Cronbach Alpha reliability coefficient for the overall scale was determined as .93. The questionnaire translated into Turkish was applied to 646 high school students, and its validity and reliability were determined. According to the results of the analysis, the number of items, which was 30 in the original questionnaire, was also preserved in the Turkish questionnaire. According to the results of the factor analysis, it was determined that the Turkish questionnaire had six dimensions, just like the original questionnaire. There are 5 items in each dimension of the Turkish questionnaire. While the Cronbach Alpha reliability coefficient was found to be .87 for the overall questionnaire, it was determined that it ranged from .80 to .89 in its dimensions. These values are similar to previous studies (Glynn & Koballa, 2006; Glynn et al., 2007; Glynn et al., 2009). Questionnaire items were arranged in a 5-point Likert type. Positive items are never: 1 point, rarely: 2 points, sometimes: 3 points, usually: 4 points, and always: 5 points, while negative items are evaluated in the opposite way. In addition, statistically significant and positive correlations were determined between the six factors in the questionnaire. It states that these relationships between the dimensions of the scale are moderate and positive, and that the scale consists of factors independent of each other (Büyüköztürk, 2006). As a result; it has been determined that the Turkish form of the biology lesson motivation questionnaire is suitable for Turkish, valid and reliable in terms of language.

At the end of the experimental process, standardized open-ended interviews were conducted with the volunteer participants. For this purpose, an interview form consisting of open-ended questions was prepared by the researchers. The interview form was evaluated by the experts in the field of curriculum development and measurement-evaluation in terms of the suitability of the questions, and by the language experts in terms of clarity. As a result the form was found appropriate to apply to the participants. As examples of the questions in the interview form; *"Do you think AR applications contributed to your learning, remembering and your achievement in the course? (If so, how did it contribute?), Do you think AR applications contributed to your interest and motivation towards the lesson? (If so, how did it contribute?), Have AR applications changed your study method? (If so, how did it change?), Do you think AR applications contributed to the classroom environment, teacher-student and student-student relations? (If so, how did it contribute?), What do you think about the software you use for AR applications?, What changes would you like to make if you were to make the application again?, Do you think that education should be supported with AR applications in the future? (If so, why it should be supported?)"* can be given.

Implementation Process and Data Collection

In the study, the experimental application was made in the *cell* unit of the ninth grade biology course. At the beginning of the application, the achievement test prepared by the researcher and the biology lesson motivation questionnaire were given to the experimental and control group students as a pre-test. The experimental process was started with the subject of *cell and organelles* subject of the *cell* unit. The biology course, in which the experimental application is made, is a 3-hour course per week and is mostly taught in the classroom environment. The experimental group students were informed by the researcher about the definition of *AR* and mobile and computer-assisted AR applications before the application. AR mobile application was installed on the phones of the experimental group students and personal accounts were created for each of them. The

students acquired visuals on the subject *cells and organelles*, and shot short videos describing the functions and properties of *cells and organelles*. In order to combine images and videos, they opened the relevant application on computers in the computer laboratory and logged into the program with their user accounts. Then they combined the pictures and videos they uploaded to the application. Finally, they introduced the pictures using the application on their mobile devices and played the videos they had uploaded in this way. While these procedures were carried out for a total of 18 lesson hours for 6 weeks, 3 lessons per week, in the experimental group; in the control group, the lessons continued in line with the current program, and the subjects were explained by the teacher.

As soon as the experimental application was completed, the achievement test and the biology lesson motivation questionnaire were applied to the experimental group and the control group as a post-test. On the other hand interviews were held with 11 students in the experimental group; at the beginning of the interviews, the purpose, importance, scope of the research and where the data obtained from the research will be used were explained to the participants; in order to facilitate the breakdown and analysis of the interview data and to prevent data loss, it was explained to the participants that the interview could be recorded with audio, and their verbal consent was obtained in this regard.

Analysis of Data

The quantitative data of the study were analyzed through IBM SPSS Statistics 24 program. For the statistical techniques to be applied in the study, the Shapiro-Wilk test was applied in order to determine whether the distribution of the measurements of the dependent variables is normal or not, taking into account the group size smaller than 50, and the test results are given in Table 3.

Table 3. Tests of normality

		Shapiro-Wilk		
	Group	Statistic	df	p
Academic achievement pre-test	Experiment	.905	17	.083
	Control	.898	21	*.032*
Academic achievement post-test	Experiment	.883	17	*.036*
	Control	.917	21	.077
Intrinsic motivation pre-test	Experiment	.952	17	.496
	Control	.886	21	*.019*
Intrinsic motivation post-test	Experiment	.887	17	*.041*
	Control	.950	21	.345
Extrinsic motivation pre-test	Experiment	.929	17	.210
	Control	.939	21	.209
Extrinsic motivation post-test	Experiment	.930	17	.219
	Control	.915	21	.070
Interest in learning biology pre-test	Experiment	.958	17	.587
	Control	.975	21	.842
Interest in learning biology post-test	Experiment	.939	17	.312
	Control	.936	21	.183
Responsibility in learning biology pre-test	Experiment	.928	17	.199
	Control	.921	21	.090
Responsibility in learning biology post-test	Experiment	.906	17	.085
	Control	.845	21	*.004*
Confidence in learning biology pre-test	Experiment	.896	17	.058
	Control	.951	21	.348
Confidence in learning biology post-test	Experiment	.929	17	.211
	Control	.899	21	*.033*
Anxiety in biology exams pre-test	Experiment	.930	17	.219
	Control	.927	21	.118
Anxiety in biology exams post-test	Experiment	.899	17	.065
	Control	.931	21	.147
Total motivation pre-test	Experiment	.937	17	.286
	Control	.943	21	.247
Total motivation post-test	Experiment	.938	17	.298
	Control	.938	21	.195

In the analysis, the statistical (null) hypothesis was established as "the distribution of scores does not differ significantly from the normal distribution", so the calculated p value was higher than $\alpha = .05$, it was interpreted as that the scores at this significance level did not show excessive deviation from the normal distribution and are appropriate (Büyüköztürk, 2007). Looking at Table 3; it can be said that most of the pretest and posttest measurements show a normal distribution. Based on this data, independent samples *t* test from parametric statistical techniques was used to determine whether there was a significant difference between the scores of the experimental group students and the control group students from the academic achievement test and the motivation questionnaire. Six different points less than $\alpha = .05$ were neglected considering the group size greater than 15.

The qualitative data obtained by the interview method were analyzed with the descriptive analysis technique. Descriptive analysis is the lowest level and simplest form of analysis in which data is shown, described, illustrated and explained as it is (Sönmez & Alacapınar, 2011). Descriptive analysis is mostly used in research where the conceptual structure of the research is clearly determined beforehand (Yıldırım & Şimşek, 2006). Since the conceptual framework and themes were determined at the beginning of the research process, the descriptive analysis method was preferred. The questions in the interview form were also effective in determining the themes. In this study, the interview data were recorded audibly and these data were listened to by the researcher on the day of the interview and recorded in the word processing program. Relevant themes were determined for descriptive analysis, the data obtained were processed according to the thematic framework and presented with direct quotations. The following validity and reliability studies were conducted in the quantitative and qualitative dimensions of the research:

1. In the study, in which quantitative and qualitative data collection methods were used together, the researchers became a natural part of the research process by spending time in the field and conducting direct interviews with the participants, both in the experimental process and the interview process. Therefore, in this study, researchers play a participant role. The closeness of the researcher to the participants increases the validity (Creswell, 2017).
2. The processes followed in preparing the achievement test and interview form used in the research are explained under the heading of data collection tools.
3. The research process was enriched with qualitative and quantitative data collection techniques. Different data collection techniques were used together to increase the credibility of the research.
4. The qualitative findings of the research were clearly presented, and participant confirmation was obtained for the data collected at the end of the one-by-one interviews with the students. The findings obtained from the interviews were presented through direct quotations to increase the transferability, and the opinions of the researchers were reflected in the interpretation stage after the data were collected and analyzed.
5. The analysis results of the collected data were examined by other researchers and experts.
6. The research process was explained in detail.

Findings

Findings Regarding the First Hypothesis of the Study

Table 3 shows the independent samples t-test results, which were conducted to determine whether the posttest mean scores of the experimental group students in which the AR applications were applied and the control group students in which the current program was applied showed a significant difference.

Table 3. The *t* test results of the students' academic achievement posttest mean scores according to the group

Group	n	x̄	Sd	df	*t*	*p*
Experiment	17	28.06	2.11	36	17.922	0.000*
Control	21	14.86	2.37			

*p≤..05.

When Table 3 is examined, it is seen that the posttest mean scores of the experimental group students are significantly higher than the posttest mean scores of the control group students ($t_{(36)}$=17,922; p≤0.05). Based on this finding, it can be said that AR applications are effective in achieving academic achievement in the ninth grade biology cell unit compared to the current application.

Findings Regarding the Second Hypothesis of the Study

Table 4 shows the independent samples *t* test results of the mean scores obtained from the biology lesson motivation questionnaire of the experimental group students in which AR applications were applied and the control group students in which the current application was applied. When Table 4 is examined, there is no significant difference between the mean scores of the experimental group students and the control group students in the motivation questionnaire for the biology lesson in terms of "intrinsic motivation, extrinsic motivation, interest in learning, responsibility in learning, trust in learning" dimensions and total score. However, a significant difference was found in favor of the experimental group in terms of "anxiety in exams" ($t(36)=2.593$; $p\leq0.05$). Based on this finding, it can be said that AR applications performed in the ninth grade biology lesson cell unit increase students' anxiety about exams compared to the current curriculum.

Table 4. The *t* test results of the students' motivation posttest mean scores according to the group

Factor	Group	n	x̄	Sd	df	*t*	*p*
Intrinsic motivation	Experiment	17	20.77	3.21	36	1.272	0.211
	Control	21	19.24	4.01			
Extrinsic motivation	Experiment	17	22.29	1.57	36	1.344	0.187
	Control	21	21.14	3.23			
Interest in learning	Experiment	17	19.00	4.05	36	0.733	0.468
	Control	21	17.86	5.29			
Responsibility for learning	Experiment	17	20.65	2.47	36	0.648	0.521
	Control	21	19.86	4.50			
Confidence in learning	Experiment	17	19.65	2.62	36	0.730	0.470
	Control	21	18.67	5.00			
Anxiety in exams	Experiment	17	20.06	2.93	36	2.593	0.014*
	Control	21	16.86	4.35			
Total	Experiment	17	122.41	11.45	36	1.688	0.100
	Control	21	113.62	18.82			

* p≤..05.

Findings regarding the Sub-problem related to the Qualitative Dimension of the Research

While the research findings related to the interviews with the participants were given, the common opinions of the participants were collected and presented together and supported by direct quotations.

Table 5. Qualitative findings of the research

Themes	Codes
Positive aspects (S1, S2, S4, S7)	It includes visuality, reflects reality, is practical, enjoyable and entertaining
Negative aspects (S4, S6, S7)	Taking time
	Not taking notes
Contribution to learning (S1, S2, S3, S4, S6, S7, S8, S9, S10, S11)	Ensuring learning by doing and experiencing, being permanent, increasing level of learning and course achievement, improving academic self-confidence
Effect on study methods	Changing study method, working with visual elements, seeing the subject more detailed, visuals draw attention, no change
Contribution to the interest and motivation for the course (S1, S2, S3, S4, S8)	Destroying the prejudices about the course, increasing interest and motivation, providing excitement and happiness, getting bored, decreasing motivation
Its effect on the classroom environment, teacher-student and student-student relations (S2, S3, S6, S7, S8, S11)	Helping, sharing, exchanging ideas, teamwork, a friendly environment
Opinions on the software used (S1, S3, S10, S11)	Being different and entertaining, providing access to information in a different way,
(S2, S6, S8)	Difficult to use, slow
Suggestions (S1, S3, S4, S7, S8, S9, S11)	Application of biology course in different subjects, physics, chemistry and geography courses.
(S4, S6)	Giving more time
(S2, S3, S7, S11)	Similar practices in other schools, supporting learning by doing and experiencing

Students participating in the research, regarding the positive aspects of AR applications; they stated that it reflects the reality, that it is enjoyable and entertaining. Examples of student views on this issue are presented below:

S1; I liked it, it was pretty good, I liked that it was hands-on and visual.
S2; I liked that the app is visual and fun.
S4; It was a great practice for me to not get bored in the lesson.
S7; I really liked that the app reflects reality.

Students, regarding the negative aspects of AR applications; they expressed the opinion that not taking notes and taking time. Examples of student views on this issue are presented below:

S4; Using the app was taking time.
S6; Applications took a long time.
S7; It was fun, but it was better when we took notes, and we didn't take notes here.

Regarding the contribution of AR applications to learning; they stated that they learn by doing and living, applications contain visuals, and they provide easy and permanent learning. Examples of student views on this issue are presented below:

S1; The class was more fun. We learned the subject better. We don't like to memorize. I think I am and will be more successful with AR applications.
S2; I remembered what I learned more easily because my visual intelligence was better.
S3; It was more permanent and fun to practice rather than reading and writing.
S4; The fact that it was hands-on rather than narrative helped us recognize and visually recall organelles.
S6; Because we did it ourselves, we learned better by seeing all the finer details.
S7; Using and applying technology has been more effective.
S8; I learned better thanks to the practical teaching of the course subject rather than being taught by writing it down.
S9; It had an effect on me learning better and remembering easily.
S10; It contributed to my achievement in the biology course, my self-confidence increased.
S11; We started to believe that we could do better on the exams.

A few of the students stated that AR applications had an effect on their study methods and they understood better visually. Some students stated that although the application attracted attention with its visual side, it still did not change their study methods. Examples of student opinions are presented below:

S8; It changed the way I study, now I started working with visual elements.
S10; My study activities have changed.
S11; While I used to perceive the cell as simple, with this application I changed my way of working because I saw that the cell and its organelles are more detailed.
S4; My study method hasn't changed, but the visuals and pictures have caught my attention.

The students who participated in the research stated that AR applications increased their interest and motivation towards the lesson and reduced their prejudices about the biology lesson. One participant stated that his motivation decreased due to the long duration of AR applications. Examples of student opinions are presented below:

S2; I started coming to biology classes more excited and happy.
S3; The studies really caught my attention and it changed my perspective on biology.
S4; With the app, my interest in biology grew.
S8; With this study, my prejudice to biology was destroyed and my motivation increased.
S1; I got bored with the applications because it took so long and my motivation dropped.

The students stated that the AR application increased the sharing and exchange of information, and made the classroom environment more friendly. Student opinions regarding this are given below:

S2; There was a more friendly atmosphere with our teacher and our friends.
S3; Our teacher helped us a lot because it was the first time we did such a practice, and sometimes teamwork was effective.

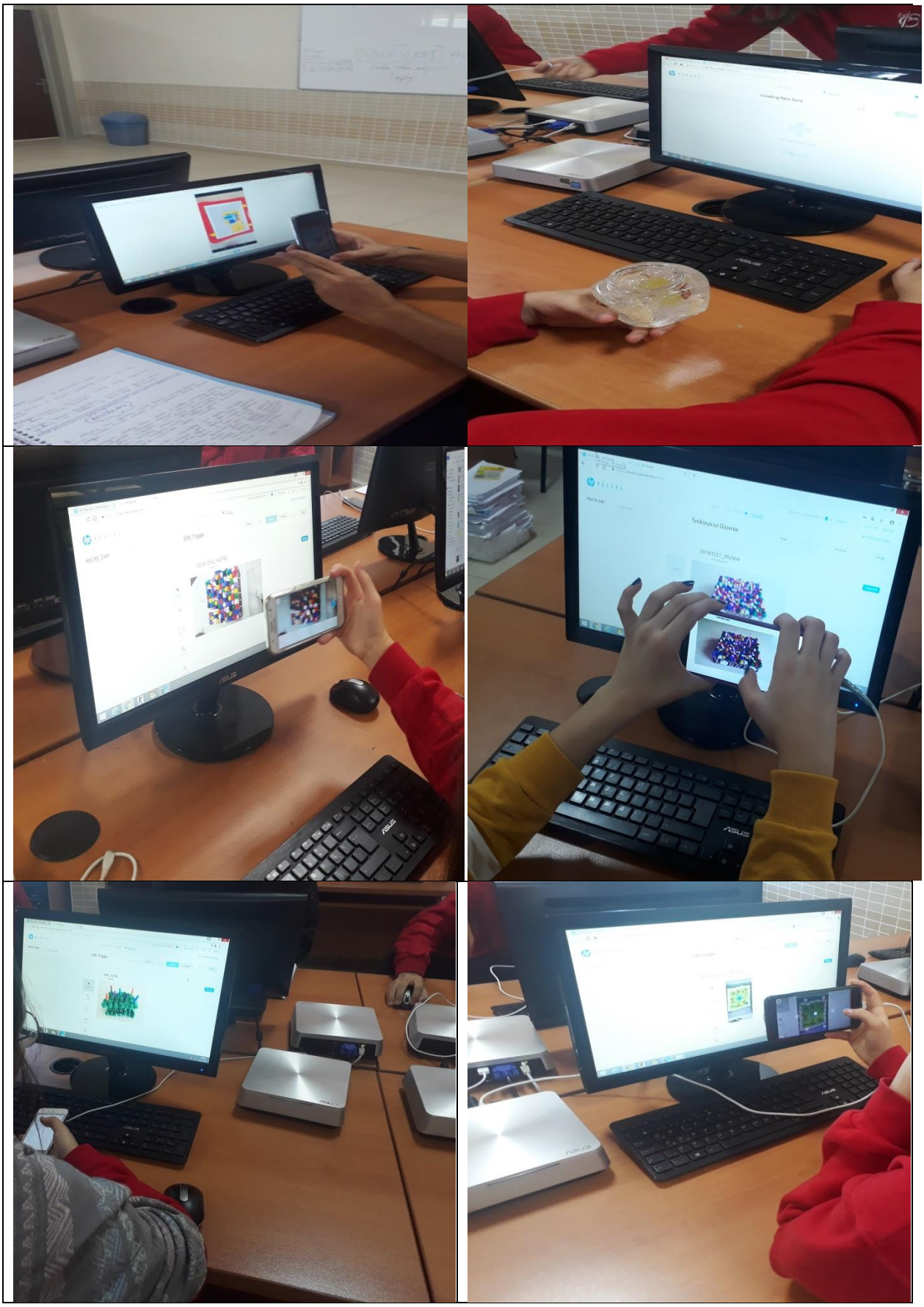

Figure 1. Visuals of AR applications

S6; We became more sincere with our teacher and our sharing with our friends increased.
S7; We exchanged ideas with our friends.
S8; We learned by discussing organelles with our friends.
S11; We got help from our teacher and helped and socialized with our friends.

While some of the students participating in the research emphasized that AR software is fun, reflects reality and has easy access to information; others stated that they had difficulties in installing and using the application and that this application should be developed. Examples of student opinions are presented below:

S1; Although I struggled a bit, it was a good application.
S3; It was a different application, more reflective of the virtual environment to us.
S10; I liked it very much because it is an application where I can access information very easily.
S11; I found the app fun and very beautiful.
S2; I had a very difficult time installing and using the software.
S6; I had a hard time introducing pictures and uploading videos. It would be better if the application was developed.
S8; It would be nice if the app was faster.

The students participating in the research stated that it would be good to make AR applications in other units of the biology course, in physics, chemistry and geography courses. Student opinions regarding this are given below:

S1; Because it is 3D, we remembered it. I would like to do it in other lessons as well.
S3; I learned the cell unit very well. If we did it in physics and chemistry classes, I would learn very well.
S4; It would be great if we could do in geography class. I would like it to be embodied in this way, as other biology subjects also remain abstract.
S7; I cannot understand many subjects in physics class, I would like to do this application in physics class as well.
S8; I would love to do it in chemistry and geography classes.
S9; This technology should be used in all courses.
S11; I would like to do it in different units as well. It should also be applied in physics and chemistry classes.

Students made various suggestions regarding AR applications. Some of these recommendations are presented below:

S2; “I think that students should be active with these and similar practices and should be supported for learning by doing.”
S3; “It would be more comfortable if the application was done in more class hours. It is an application where we will be more successful by learning through the concretization of abstract concepts.”
S7; “This practice should definitely be done in other schools as well.”
S11; “AG studies should be supported in education and in our country.”

The students' views on AR applications are stated above. In Figure 1 above, visuals of AR applications are given.

Discussion and Conclusion

When the findings related to the first hypothesis of the research are examined, it was seen that the achievement posttest point averages of the experimental group students were significantly higher than the posttest averages of the control group students. Based on this finding, it can be said that AR applications are effective in achieving academic achievement in the ninth grade biology cell unit compared to the current curriculum. This finding can be interpreted as the use of AR supported teaching materials in science education will provide positive learning outcomes. This finding shows parallelism with the qualitative findings of the study. The participants of the study stated that AR applications enable learning by doing and experiencing, increase the level of learning and academic success, that what they learn in this way is permanent and their academic self-confidence improves. In addition, the students evaluated the applications positively in terms of including visuality, reflecting the truth, being enjoyable and entertaining, increasing interest and motivation, providing excitement and happiness, and destroying the prejudices about the lesson. All these factors can be seen as factors that have positive effects on

academic achievement. When the relevant literature is examined, it has been seen that similar results have been reached in many studies (Abdüsselam & Karal, 2012; Alınlı & Yazıcı, 2020; Bacca et al., 2014; Eroğlu, 2018; Ersoy et al., 2016; Girgin, 2018; Gün & Atasoy, 2017; Ibáñez et al., 2014; İbili, 2013; Kırıkkaya & Şentürk, 2018; Küçük et al., 2014; Özbek & Ak, 2020; Özdemir & Özçakır, 2017).

When the findings related to the second hypothesis of the research are examined, no significant difference was found between the motivation total score averages of the experimental group and the control group students and the sub-dimension averages of intrinsic motivation, extrinsic motivation, interest in learning, trust in learning and responsibility in learning. Affective variables such as attitude, motivation, academic success, etc. can change over a longer period of time compared to other variables. The 6-week experimental period may not be enough time to see a significant difference in motivation scores. On the other hand, the experimental group students stated that AR applications increased their interest and motivation towards the lesson, and thus they came to the lessons more enthusiastically and excitedly. When the studies on AR applications are examined, it can be seen that the effective use of new technologies such as AR in education can affect students' imaginations, improve their creativity, and increase their motivation and attitudes towards the lesson (Arıcı, 2013; Ersoy, Duman & Öncü, 2016; Uluyol & Eryılmaz, 2014). Many studies on the use of technology in learning activities suggest that learning environments using AR can increase learning motivation and effectiveness (Huang et al., 2016). Since AR environments have the ability to attract students' attention easily, students can adapt to the subject they are interested in more easily (Winkler et al., 2002). In this context, AR technology can offer new opportunities to promote learning.

In this study, it was determined that the motivation questionnaire "exam anxiety" sub-dimension score averages were higher in the experimental group, in other words, students who performed AR applications approached exams with anxiety. Exam anxiety is defined as intense anxiety that prevents the previously learned knowledge from being used effectively during the exam and leads to a decrease in success (Sarıkaya & Gemalmaz, 2021). The fact that the student stands out with her study feature, keeps her grades high and fulfills what is asked of her in the lessons causes her to be considered academically successful (Kaya et al., 2012). The students' encounter with a new application may have caused them to think that they could face a new situation in the exams. Or, because they have studied in a different way than before, they may not be aware of how much they have learned and may have doubts about using the information they have learned in the exam. Although the students generally liked this application and stated that it facilitated their learning and increased the permanence of what was learned, it can be said that this application did not relieve their worries about the exams.

When the findings regarding the sub-problem related to the qualitative dimension of the research are examined, students participating in the research; stated that they like biology lessons in which AR applications are carried out; they found the applications different, enjoyable and entertaining, and the applications helped to embody abstract concepts and make the subjects more memorable; They stated that cooperation between the students and the teacher increased in the classroom and learning by experience took place. Students, who stated that their interest and motivation towards the lesson increased thanks to the applications, suggested that these and similar applications be used in different units and subjects of the biology lesson, in other fields of science such as physics and chemistry, and in the geography lesson. The results of similar studies in the literature largely support the findings obtained from the interviews with the students in this study. The findings of the researchers, who determined that AR applications embody abstract concepts, increase attention and motivation, increase student participation by creating a learning environment by doing, provide learning with fun, improve interaction and cooperation in the classroom, are in line with the results of this study (Huang et al., 2016; Ivanova & Ivanov, 2011; O'Brien & Toms, 2005; Squire et al., 2008; Walczak et al., 2006; Wei et al., 2015; Wojciechowski & Cellary, 2013; Yoon et al., 2012).

Today, many researches on educational technologies show a tendency towards emerging technologies. Educational applications developed for use on desktop computers, tablets and mobile phones enrich the imagination of students with the help of various multimedia elements brought together, embody abstract concepts and add excitement to learning (Timur & Özdemir, 2018). Using the ever-evolving technology, and presenting the lessons by making use of technological devices, is of great importance for students to better understand the subject and to be interested in the lesson. In this way, students can come to the lesson more willingly, concentrate on the lesson and lose their interest later than in a normal lesson. In addition, such practices, in which contemporary techniques are used instead of classical methods to prepare a course material, can provide new perspectives on education (Avcı & Taşdemir, 2019). In line with these views, it can be said that an innovative technology such as AR can bring a new breath to the teaching of subjects that are difficult in the field of science. Nowadays, when we can see a wide variety of applications of AR in education, the ability to

connect reality and digital content is constantly evolving and offers more options for teachers and students day by day (Girgin, 2018).

If another result of the research is mentioned; some of the students stated that the applications take time, they have difficulties in some stages and the software needs to be developed. The inadequacy of students' knowledge and experience about technological applications and instructional software may cause these opinions and misconceptions about the effectiveness of the application. In addition to these, the fact that students who meet a new application are more active by getting rid of the traditional ways they are used to may have caused this result and some difficulties.

Developments in information and communication technologies offer us new opportunities in the field of education. AR technology can make classrooms more engaging and knowledge more applicable. A large proportion of teenagers today own smartphones, and many of them are active smartphone users who use these tools to play games and connect with friends. A much smaller proportion of teens use their phones to do homework, gather information on a topic, etc. uses for educational purposes. When smartphones and AR are combined for education, students can be given extra digital information about any subject in various ways and complex information can be made easier to understand (Girgin, 2018).

Recommendations

It has been determined that biology lessons taught with AR activities are more effective in increasing academic achievement than the lessons taught with the activities of the current program. For this reason, it is thought that including AR applications in curricula and lesson plans, focusing on the use of activities with AR applications in the lessons will increase the academic achievement of the students and a high level of efficiency will be obtained from the teaching activities carried out in this way. The important thing here is to ensure that AR applications are suitable for the level of students. It can be said that the implementation of activities supported by AR in educational institutions will bring a different perspective in terms of the integration of technology into education. It was concluded that there was a significant difference in favor of the experimental group in the "anxiety in exams" sub-dimension of the motivation questionnaire, and the AR activities applied to the experimental group students caused the students to worry about the exams. It is normal for students who are introduced to a new application to worry about what they will do and what they will encounter in the exams. It is thought that such anxieties of students will decrease with the use of similar technological applications more in lessons.

When the findings about the challenging aspects of these activities of the experimental group students, in which AR applications were made, were examined, it was concluded that some students had problems with insufficient lesson hours and long applications. In this case, it can be suggested that the time allocated to AR applications should be arranged in line with student opinions. In addition to the fact that the mobile application used in the research is largely useful, it has been revealed that it perceives the pictures difficult and there are problems in loading them. It is thought that the mobile application should be developed in order to avoid these problems in new applications to be made in the future. Students who like to learn with activities based on AR applications stated that they want to use this application in physics, chemistry and geography lessons. In this direction, it can be suggested that AR applications should be used more in other lessons, especially in lessons that students find abstract and have difficulties. In this study, the effect of activities based on AR applications on student achievement and motivation in biology lesson was tried to be measured. Researchers who will study on this subject may be advised to investigate the effects of similar practices on variables such as interest, attitude, and permanence of what has been learned.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors.

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