The effects of Augmented Reality applications on the academic achievement and motivation of secondary school students

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ABSTRACT

This research aims to reveal the effects of using augmented reality applications on seventh-grade secondary school students' academic achievement and motivation and to identify students' views on augmented reality applications. For this purpose, the augmented reality application called "CellAR" has been developed for the "Cell and Cell Division" unit. The study used pre-test - post-test control group quasi-experimental design research method and general survey model. During the research, the experimental group students used the CellAR augmented reality learning application developed by the researcher in addition to the regular course materials (textbooks, e-books, printed materials, videos, visuals, etc.). In contrast, the students in the control group used only the regular course materials. An academic achievement test, motivation scale, and opinion questionnaire for augmented reality application were used to collect data. T-test for independent samples, single-factor analysis of covariance (ANCOVA), and descriptive statistics were used. According to the results, the academic achievement and motivation of the students in the experimental group using augmented reality application were significantly higher than the students in the control group. According to descriptive results, the students thought that the augmented reality application helped them learn the subjects, facilitated the concretization of abstract concepts, and provided active learning experiences. Similarly, the students found the augmented reality application interesting and stated that it increased their creativity and motivation.

Keywords: Augmented reality, academic achievement, motivation, science education, educational technology

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INTRODUCTION

In parallel with the developing technology, there have been developments in simulation software that allow simulations of experiments or phenomena that are otherwise impossible in real life to facilitate educational activities (Hartman & Bertoline, 2005). Two well-known and noteworthy technologies are virtual reality (VR) and augmented reality (AR) applications. Virtual reality is a system where imaging and interface technologies provide interactive 3D features created in a computer environment (Pan et al., 2006). AR is a technology that supports real-time interaction that allows physical and virtual objects to coexist (Matcha & Rambli, 2013) and combines the physical world with virtual images, graphics, and sounds (Delello, 2014).

Therefore, it is thought that AR technology, which enables the coexistence of virtual and real objects, can be used more efficiently in the education and training processes. In contrast, VR is created in a completely virtual environment that lacks the element of natural and physical interaction (Matcha & Rambli, 2013).

AR applications, which offer real-time interactive environments, combine real and virtual properties and allow users to see objects in three dimensions (Azuma, 1997; Daniela & Lytras, 2019; Turan & Atila, 2021). AR applications are used to develop cognitive and affective skills (Jamali et al., 2014; Yılmaz & Batdı, 2016) in the education and training processes. Therefore, the effect of students' achievements on the development of cognitive skills and the motivation of students for the development of affective skills was investigated in the study.

Using Augmented Reality in Education

With the advancing information technologies, AR applications have started to be used widely in many fields, such as education, tourism, health, and engineering (Azuma, 1997; Cheng & Tsai, 2013; İbili & Şahin, 2013; Küçük et al., 2015). Although AR technologies have recently entered educational environments (Fleck et al., 2014), they have been widely used in educational settings, due to their student-centered nature (Delello, 2014) and for their appropriateness for situational learning (Taşkıran et al., 2015; Wojciechowski & Cellary, 2013; Wu et al., 2013). Moreover, they provide an authentic learning environment (Wu et al., 2013) and create active learning experiences for students (Singhal et al., 2012). Many advantages of AR applications on cognitive and affective dimensions are mentioned in studies examining the use of AR technologies in educational environments in the literature. Examples of these are as follows:

- Affective dimensions:
  - They are striking and increase the attention of younger students to the subject (Delello, 2014; Tomi & Rambli, 2013).
  - They increase the active participation of students in the lessons (Bai et al., 2013; Turan & Atila, 2021).
  - They make the learning process enjoyable (Tomi & Rambli, 2013; Zarzuela et al., 2013).
  - They increase students' motivation toward the lesson (Jamali et al., 2014; Kerawalla et al., 2006; Küçük et al., 2014).
  - They increase the students' engagement in learning activities (Jamali et al., 2014; Yoon et al., 2018).
- Cognitive dimensions:
  - They make learning comprehensible and easy by concretizing abstract concepts, especially for students in the concrete development period (Abdüsselam, 2014; Taşkıran et al., 2015).
  - They enable students to reach the expected goals in learning faster by facilitating understanding and comprehension (Cai et al., 2014; Çetin & Türkan, 2021; Delello, 2014; Jamali et al., 2014; Shelton & Stevens, 2004).
  - They offer students the opportunity to access, see, and examine objects they cannot see in the real world (Wu et al., 2013; Yuen et al., 2011).
  - They provide students with a learning environment and difficult or impossible experiences to implement in a real environment (Wojciechowski & Cellary, 2013).
  - They create an environment for students for collaborative learning (Fleck et al., 2014; Medicherla et al., 2010).
  - They improve students' spatial thinking skills (Kaufmann, 2003; Özçakır & Çakıroğlu, 2021).
  - They enable students to interact with virtual objects in the natural environment and have active learning experiences (Cai et al., 2014; Matcha & Rambli, 2013).

AR applications in science education

Many AR applications are prepared for different subjects on the Internet, considering the advantages of augmented reality in education. One is the ARfract application, developed for AR simulation-based learning environment, can be installed at a science museum. Using the app, students can learn about complex scientific concepts related to the refraction of light through whole-body immersion (Oh et al., 2018). Another application, The Star Chart AR, allows people interested in astronomy to view celestial objects such as stars, constellations, and comets (Star Chart, 2019). Furthermore, Euclidean Lands AR, a game-based application, aims to improve spatial and geometry skills (Euclidean Lands, 2019). Another application, Blippar, provides an AR environment where teachers and students can develop and use their content consisting of sound, video, visuals, three-dimensional objects, and animations (Blippar, 2019). Finally, although there are not many, there are also AR applications developed specifically for biology concepts. One of them is Eukaryo (Yuen et al., 2016), a simulated biomolecular world that enables users to explore the complex environment within a biological cell. Users could also use multiple modes to explore the cell, its structural elements, organelles, and some key metabolic processes. Another application, HUMAR, is a learning tool designed to increase student motivation and improve learning outcomes in skeletal anatomy (Jamali et al., 2015). Also, APPLearn (Heart) was developed to help students visualize the cardiac and circulatory system, such as the structure of arteries and veins, valves, atria, and ventricles (Ba et al., 2018).

Significance of the study

Genetics is a complex subject based on understanding the structure and molecular behavior of chromosomes that carry information, and many students have difficulties in this regard (Arslan et al., 2015; Newman et al., 2012; Williams et al., 2010). Also, although students' problems with cell division are a widely recognized problem, and many teaching approaches have been devised in attempts to solve it, little progress has been made (Newman et al., 2012; Williams et al., 2010). Field-specific terminology, the abstract nature of genetic concepts, and alternative concepts are among the main challenges in understanding cell division concepts (Arslan et al., 2015). Many researchers emphasize that traditional teaching strategies slightly affect students' meaningful understanding of inheritance (e.g., cell division). They suggest that significant changes should be made in curriculum planning and the sequencing of teaching when genetics is taught at the secondary school level (e.g., Arslan et al., 2015; Goff et al., 2017).

AR offers many important components for educational settings, such as concretizing abstract concepts, enhancing three-dimensional thinking skills, providing three-dimensional materials, increasing motivation, and providing an interactive environment (Alexander et al., 2019). Skills in 3D modeling, programming, and content development are required to develop effective AR applications, and there are challenges in bringing together experts in these areas (Jamali et al., 2014). It is important to diversify AR studies in education, which is thought to be in its infancy, to reveal the real effects of these applications in the education process and determine the correct implementation methods and techniques (Cai et al., 2014; Matcha & Rambli, 2013). Similarly, a limited number of studies in Biology investigating the use of AR applications developed especially for Biology (İçten & Bal, 2017). To emphasize this shortage, Erbas and Demirer (2019) expressed that the number of existing studies on the use of AR in biology education is limited (e.g., Chang et al., 2016; Hung et al., 2016), focus on specific biology contents, and focus on a narrow population. In addition, a limited number of studies use AR applications prepared under the supervision of teachers, subject experts, and instructional technologists in the specific subjects of biology in science courses (Küçük et al., 2015; Marzouk et al., 2013). This study aimed to examine the effect of the use of AR application (prepared under the guidance of instructional technologists, subject experts, and teachers of the course) on the academic achievement and motivation of the 7th-grade students of the "Cell and Cell-Division" unit. In addition, it was aimed to examine the students' views who have used the AR application, considering that it will contribute to the interpretation of the results on achievement and motivation. For that reason, the following research questions were formed for the study:

- Does the use of AR material make a significant difference in the academic achievement of students?
- Does the use of AR material make a significant difference in students’ motivation?
- What are the students’ views on the use of AR material in the lesson?

METHOD

Research model

The research was conducted using the pre-test - post-test control group quasi-experimental design (Borg & Gall, 1989; Büyüköztürk, 2007; Hovardaoğlu, 2006; Kerlinger, 1973) research method to determine the effect of the use of AR applications on the academic achievement and motivation of the students and the general survey model (Karasar, 2016) to reveal students’ views on AR application. The study group consisted of 54 students from four classrooms studying in the 7th grade in two different branches of a private secondary school. Two classes from each branch participated in the study; one class was assigned to the experimental group and the other to the control group in each branch. Private schools and students studying in these schools were selected because private schools have more opportunities to access educational technologies. The students were not randomly assigned to the classes, but they were randomly assigned to the experimental and control groups in the study. Ethics Committee Approval was received from "Bolu Abant İzzet Baysal University, Human Research Ethics Committee in Social Sciences" with the protocol number 2019/246 dated 10.08.2019.

Instruments

Achievement test: An achievement test was developed to determine students' academic achievement before and after the implementation of the “Cell and Cell Divisions” unit. To develop the achievement test, a multiple-choice test consisting of 34 questions (taking into account the objectives under the supervision of the experts of the subject and the teachers of the course) was prepared for the acquisitions of the “Cell and Cell Divisions” unit. To ensure the content validity of the test, the opinions of three science teachers who are experts in their fields were obtained, and two questions were removed from the test as suggested by the teachers. It was applied to 20 7th-grade students studying at a public school to test their comprehensibility of the test. The KR-20 reliability coefficient of the academic achievement test consisting of 32 questions, which was piloted, was calculated as .83. Five questions with a discrimination degree below .30 from the questions in the academic achievement test were removed, and an academic achievement test consisting of 27 questions was created. The reliability coefficient of the final test was calculated as .85. The discrimination coefficients of the questions vary between .35 and .81. The average degree of discrimination was calculated as .52.

Motivation scale: The Motivation Scale for Science Learning, developed by Dede and Yaman (2008), was used to measure whether there was a significant difference in the motivation of 7th-grade students for the Science course with the use of AR application in the Cell and Cell Division unit. Dede and Yaman (2008) developed the questionnaire through a literature survey and consulted subject experts for their evaluation. Then, they applied the scale to 183 secondary school students to revise the questionnaire before applying to 421 secondary school students. According to the exploratory factor analysis, five factors explaining 47% of the total variance (motivation for research, performance, communication, participation, and cooperation) have emerged as a structure. The scale consists of 23 items in a 5-point Likert type. The reliability coefficient of the scale (Cronbach Alpha) was .80. The reliability coefficient (Cronbach Alpha) of the scale in this study is calculated as .82.

Student opinion questionnaire for AR applications: To determine the opinions of 7th-grade students about the AR application used for the “Cell and Cell Division” unit of the Science course, a student views questionnaire was administered to the AR application prepared by Taşkıran et al. (2015). The survey model, one of the quantitative research methods, was used to develop the questionnaire. The questionnaire consisted of 20 items in 5-point Likert type. The researcher calculated the reliability coefficient of the questionnaire by administering it to the experimental group at the end of the study since there was no group working with AR application before, and its reliability coefficient (Cronbach Alpha) was calculated as .82.

CellAR Application

In developing the application for the suitability of the prepared CellAR application, two science teachers, one instructional technologist, and one science expert were consulted. In line with the opinions of these experts, necessary corrections and improvements were made to finalize the application.

CellAR application is a pointer-based AR (uses pre-prepared graphics to initiate access to relevant content) application created to be used in the Cell and Cell Division unit of the Science course. It was created to be used on all devices with Android operating systems. The CellAR application allows students and teachers to interact with models that offer the closest experience to real life and make it easier for students to embody concepts. For the CellAR application, three sub-applications called Cell, Cell to Organism, and Cell Divisions have been developed, and three pointers have been created to run these applications. While preparing the pointers, the keywords related to the subject were determined, and the pointers were created using these words.

The students used the pointers created by the researcher to reach the contents in the CellAR application. Pointers are produced differently for each sub-application and have been prepared using the keywords found in the content of each sub-application. Therefore, students were able to easily distinguish between pointers to access whichever sub-application they wanted to see.

Implementation Process

Table 1. ***Timeline of The Implementation by Weeks***

Week	Process
Week 1	Pilot implementation and administration of pre-tests
Week 2	Actual implementation
Week 3	Actual implementation
Week 4	Actual implementation
Week 5	Actual implementation
Week 6	Administration of post-tests and student opinion questionnaire

Pilot Study: After the CellAR application was prepared, a pilot study was conducted with 18 students in the 8th grade in a private secondary school to see the application's shortcomings. The problems encountered in the pilot study conducted with 8th-grade students who had previously learned the Cell and Cell Division unit during four lesson hours were as follows: trying to point the pointer directly to the camera instead of the camera in the app, the inability to point the pointer to the camera in the app fully, the inability to examine the models in practice from wide and different angles, and trying to move the pointer closer to the phone instead of rotating or focusing on objects using the phone’s screen. As a result of the pilot implementation, it was decided to have the researcher as an assistant in the lessons to prevent similar technical problems from occurring during the reel implementation.

Real Study: To eliminate differences in teaching practices in student groups consisting of four classes, one class in both branches were chosen as the experimental group and one class as the control group. In both branches, 7A classes were determined as the experimental group and 7B classes as the control group by random assignment. The research process was carried out with 54 students and two Science teachers. The implementation process took six weeks, including the pilot application, pre-test, post-test, and actual implementation process (See Table 1). Students brought mobile phones with Android operating systems to the lesson during practice (See Figure 1). In all the courses where AR was applied, the researcher was present in the classroom in case of potential application problems. During the implementation of the study, while the students in the experimental group used the AR material developed by the researcher along with the course materials, the students in the control group used only the regular course materials (e-books, videos, animations, visuals, etc.).

Figure 1. ***Real Implementation***

Data Analysis

One-factor analysis of covariance (ANCOVA) was planned to analyze whether there was a significant difference between the post-test academic achievement mean scores corrected according to the average pre-test scores of the students in the experimental group using AR application and the corrected academic achievement post-test average scores of the students in the control group. However, ANCOVA analysis could not be applied because one of the necessary assumptions (homogeneity of the variances) were violated (Field, 2013). For this reason, the independent samples t-test was used to analyze whether the difference between the mean scores of the two independent groups was significant.

One-factor ANCOVA was used to analyze whether there was a significant difference between the post-test motivation average scores corrected according to the average pre-test scores of the experimental group and the corrected post-test average scores of the students in the control group. Before the analyses, the assumptions of ANCOVA were checked, and no violation was detected. Descriptive analysis was used to analyze the questionnaire applied to determine student views.

FINDINGS

The effect of using AR applications in the science course on students' academic achievement

The pre-test and post-test of the experimental and control group's academic achievement tests were analyzed to interpret the significance of the academic achievement levels of students in the experimental and control groups. The students' average pre-test academic achievement scores in the experimental group were M = 27.04 (SD= 5.10) and M = 28.82 (SD= 4.09) in the control group. A statistically significant difference was not observed between the experimental and control groups according to the results of the independent samples t-test (t (52) = -1.41, p=0.16) for the pre-test scores.

The independent samples t-test was used to reveal whether AR applications in the cell and cell division unit significantly affect students' academic achievement. The students' average post-test academic achievement scores in the experimental group were M = 88.89 (SD= 2.95) and M = 65.93(SD= 6.78) in the control group. A statistically significant difference was observed between the groups according to the results of the independent samples t-test (t (35,51) = 16.13, p=0.00) for the post-test scores. In this case, it can be said that the AR application has a significant and positive effect on students' academic achievement when compared to the control group using only the regular course materials.

The effect of using AR applications in science lessons on students' motivation

One-factor analysis of covariance (ANCOVA) analysis was used to examine whether there was a significant difference between the post-test average motivation scores corrected according to the average pre-test scores of the students in the experimental group using AR application and the post-test average motivation scores corrected according to the average pre-test scores of the students in the control group. According to the significance test results (p = 0.00) between the mean scores of the adjusted scores in the groups, using AR application on students' motivation towards the Science course was significant in favor of the experimental group (Table 2).

Table 2. ***Covariance Analysis Table of Posttest Motivation Scores***

Source	Sum of squares	df	Mean Square	F	p	Partial (η2)
Corrected model	5,15	2	2,58	35,52	,00	,58
Intercept	6,08	1	6,08	83,93	,00	,62
Mot. pre-test	1,609	1	1,609	22,192	,000	,303
Group * Mot. pre-test	2,887	1	2,887	39,828	,000	,438
Error	3,697	51	,072			
Total	873,368	54				
Corrected Total	8,848	53				

R Squared = ,582 (Adjusted R Squared = ,566)

Students' views regarding the use of AR application in the science course

When results of the descriptive analysis for the student opinions questionnaire were examined based on sub-dimensions, it was observed that students generally have positive thoughts regarding using AR applications in science courses. Descriptive statistics of the relevant dimensions are shown in the following tables.

Table 3. ***Applications of AR as Learning Material***

Items	N	X	SS	% of "I agree" or I absolutely agree"
1. It helps me learn.	27	4.25	0.81	%77.78
2. It helps me embody/understand abstract concepts.	27	3.96	0.85	%70.38
3. I find it interesting.	27	4.33	0.68	%88.88
4. It provides learning experience by doing.	27	4.07	1.14	%74.08

5. It provides rich learning content.	27	3.96	1.11	%62.96
6. It increases my creativity.	27	4.11	0.97	%66.67
7. It increases my motivation.	27	4.07	0.92	%70.37
Total	27	4.11	0.92	%73.02

As seen in Table 3, it was determined that almost three out of four students held a positive opinion about AR applications as learning material. In this category, students gave the highest score to the fourth and first items, respectively.

Table 4. ***Views on AR Application on Students' Interactions and Benefits***

Items	N	X	SS	% of "I agree" or I absolutely agree"
8. It increases my interaction with the course content.	27	3.93	0.92	%77.78
9. It enables my active participation in the learning process.	27	3.96	0.90	%74.04
10. It makes it easier for me to reach my learning goals.	27	4.07	0.92	%81.48
11. It makes me more efficient.	27	4.04	1.06	%77.78
12. Using it increases my learning performance.	27	3.93	0.96	%66.66
13. It helps me have more control over learning activities.	27	3.93	1.07	%66.67
14. Using it saves me time.	27	3.93	0.78	%66.67
Total	27	3.97	0.94	%73.01

As seen in Table 4, it was determined that almost three-quarters of the students thought positively about the interaction and benefits provided by AR application. In this category, students scored highest on the 10th, 11th, and eighth items, respectively.

Table 5. ***Students' Views on Their Satisfaction with AR Application in Terms of Its Convenience***

Items	N	X	SS	% of "I agree" or Absolutely I agree"
15. I think it is easy to use.	27	3.78	1.09	%62.96
16. I think most people can learn to use it easily.	27	3.96	1.06	%59.29
17. I am pleased to use it.	27	4.26	0.76	%88.89
18. I would recommend using it to a friend.	27	4.04	1.02	%66.66
19. Learning to use it is fun.	27	3.93	1.07	%66.67
20. I would love to use it again in the future.	27	3.78	1.01	%59.26
Total	27	3.96	1.00	%67.29

As seen in Table 5, it was observed that almost 70% of the students were satisfied with their experience using the AR application, and they were of the idea that it was user-friendly. It was seen that the students gave the highest score in this category to the item stating that they were satisfied because they used the application. On the other hand, although the students had positive thoughts about the items related to reuse and easy use of the application, as in the other items in the questionnaire, it was observed that they gave the lowest score to these two items.

DISCUSSION AND CONCLUSION

As a result of the analysis conducted to examine the effect of the use of AR applications on the academic achievement of the 7th-grade students learning Cell and Cell Division unit, it can be concluded that the students in the experimental group using AR application were significantly and positively achieved academically more than the students in the control group. This study reached conclusions that support other studies in the literature (e.g., Abdüsselam & Karal, 2012; Çetin & Türkan, 2021; Fleck et al., 2014).

AR applications are highly effective tools in learning and teaching (Fleck et al., 2014; Matcha & Rambli, 2013; Medicherla et al., 2010). It is thought that AR application, which is seen to have a positive effect on students' academic achievement, also increases students' interest and attention (Delello, 2014; İbili, 2013). It is estimated that students' academic achievement may have increased by increasing their interest and attention thanks to the three-dimensional and realistic images (İbili, 2013) provided by the AR application of cells and organelles that were difficult to encounter in real life before.

With the AR application, students can have the opportunity to play an active role in the lesson (Delello, 2014). The active role of students in the lesson (for example, being able to ask the teacher more questions about the subject, being more attentive to the parts that interest them, and interacting with as many materials as they want) could positively affect their academic achievement with a better understanding of the subject (İbili & Şahin, 2013). In addition, some researchers state that the AR application positively affects students' motivation (e.g., İbili & Şahin, 2013; Küçük et al., 2014; Matcha & Rambli, 2013; Taşkıran et al., 2015) and this increase in student motivation could have also contributed positively to their academic achievement. Furthermore, it is thought that the use of AR applications may have increased students' academic achievement by reducing their fears and anxieties about the lesson and helping them develop a positive attitude (İbili, 2013). The findings from the opinion questionnaire also support the aforementioned view that the students have a positive attitude toward the courses using AR. Therefore, students' active role in the lesson and being able to ask questions to their teachers, getting rid of their fears and anxieties about the lesson, an increase in their interest, attention, and their motivation may have helped to eliminate the obstacles to academic achievement (İbili & Şahin, 2013; Matcha & Rambli, 2013). Significantly, the higher academic achievement of the experimental group students using AR application compared to the control group students may be due to these advantages (e.g., increasing students' interest and attention, having an active role of students in the lesson, increasing student motivation, reducing student fears and anxieties, having positive attitudes toward using AR) provided by the AR application.

As a result of the analysis conducted to examine the effect of AR applications on students' motivation in the Science course, it can be concluded that the views of students in the experimental group using the AR application were significantly different from those of the students in the control group. Thus, the students in the experimental group have a higher motivation than those in the control group. This study supports the results already found in the literature. (e.g., İbili & Şahin, 2013; Matcha & Rambli, 2013; Taşkıran et al., 2015).

The AR application, which enables students to play an active role in the learning process, allows them to participate more in the lesson (Delello, 2014; İbili & Şahin, 2013; Rosenbaum et al., 2007). Since the AR application facilitates active participation throughout the learning process, it may have positively affected the students’ motivation to actively engage in the course (Bai et al., 2013; Karal & Abdüsselam, 2015). It is thought that the use of AR applications in lessons enhances students’ motivation, as the AR application supports collaborative work, as well as facilitating expression of opinions by students during group work, demanding detailed explanations from their teachers while learning the subject, and making an effort for in-depth learning (Bai et al., 2013; Cai et al., 2014). In addition, the development of positive attitudes in students toward learning new information and existing ideas and science subjects not included in the curriculum may be due to their increased motivation (Doğan, 2016; Küçük et al., 2014). The findings from the opinion questionnaire applied to the students also support these findings/results. The AR application, with its user-friendly and fun nature, may have increased student motivation by offering them a hands-on learning experience, enabling more interaction with the course content, increasing creativity, and delivering rich learning content (Delello, 2014; Özarslan, 2013; Taşkıran et al., 2015; Tian et al., 2014). Significantly, higher motivation in the experimental group using the AR application compared to the control group students may be due to these advantages provided by the AR application.

The results of the opinion survey applied to the experimental group of students discussed item by item in the following paragraphs. First of all, the students stated that the AR application helped them learn. Studies on this subject in the literature also support that AR application helps students learn and facilitates their learning (İbili & Şahin, 2013; Korucu et al., 2016). Second, the students stated that the AR learning application involves abstract concepts. This result overlaps with other studies in the literature (e.g., Karal & Abdüsselam, 2015; Taşkıran et al., 2015). Since the unit of “Cell and Cell Divisions” has content that students have difficulty concretizing (Tekkaya et al., 2001), the AR application is thought to have facilitated student learning with its concretization feature. This also supports the result that the students in the experimental group academically achieved more than those in the control group. The students stated that it was easier to learn with the AR application, which enables them to access an environment that they cannot create in the classroom environment in three dimensions (Taşkıran et al., 2015). Many studies in the literature show that AR application offers an easier learning environment (Abdüsselam, 2014; Billinghurst et al., 2001; Cai et al., 2014; Delello, 2014; Kaufmann, 2003; Kerawalla et al., 2006; Rosenbaum et al., 2007; Shelton & Hedley, 2002; Shelton & Stevens, 2004; Tian et al., 2014).

The students added that the AR application is interesting and fun, and it provides a first-hand learning experience by doing. Studies in the literature support this claim (Delello, 2014; Korucu et al., 2016; Taşkıran et al., 2015). The lesson must be interesting and entertaining for Generation Z students, who use technological tools in their daily lives. Traditional materials are common for these students and cannot optimally attract their attention to the teaching content (Somyürek, 2014). It is thought that the AR application offers different, realistic, and three-dimensional environments (Azuma, 1997). This environment may help students find the AR application interesting. It may also enable them to have active learning experiences (Tian et al., 2014) because they directly contact the material the AR application provides. As emphasized in numerous studies in the literature, students stated that the AR application makes learning a fun activity (e.g., Matcha & Rambli, 2013; Taşkıran et al., 2015; Tomi & Rambli, 2013; Zarzuela et al., 2013).

Most students stated that the AR application contains rich learning opportunities, increases their creativity, facilitates them to reach their learning goals, increases their learning performance, and makes them more efficient. This result overlaps with other studies in the literature (Doğan, 2016; Küçük et al., 2014; Taşkıran et al., 2015). Therefore, it is thought that AR application includes rich learning opportunities and increases students' creativity by presenting content that supports visual, three-dimensional, and active participation (Taşkıran et al., 2015).

The students mainly stated that the AR application increased their motivation for the lesson. This is because the AR application easily attracts students' attention to the lesson (Delello, 2014; İbili & Şahin, 2013; Tomi & Rambli, 2013) and increases their motivation (Delello, 2014; Fleck et al.,. 2014; Kerawalla et al., 2006; Küçük et al., 2014; Taşkıran et al., 2015; Tomi & Rambli, 2013) as mentioned in various studies.

The students also mainly stated that the AR application increased interaction with the course content, enabled them to actively participate in the learning process, and helped them have more control over the learning activities. This result is supported by studies stating that the use of AR applications increases the interaction with the course content and participation in the learning process and provides more control over learning activities (Abdüsselam & Karal, 2012; Bai et al., 2013; Cai et al., 2014; Delello, 2014; Yusoff & Dahlan, 2013). Furthermore, AR application enables students to think more about the subjects (Özarslan, 2013). Therefore, while students ask more questions, they can actively participate in the class and establish a connection between real life and the studied topics (Delello, 2014). Considering the above information, AR application may have positively affected students' participation by attracting them to the lesson.

The students stated that it is easy to use AR application. During the use of the application, no training was given to the students on how to use the AR application, and the students were able to use the application in a natural process. This process shows that AR application is a learning tool that can be used easily. Similar findings are also highlighted in the literature (Özarslan, 2013; Taşkıran et al., 2015; Tian et al., 2014). During the development of the AR application, taking the opinion of field experts, eliminating the deficiencies by implementing a pilot study, and creating an easy-to-use learning application may have helped students think that way about the application. It was seen that the students would like to use the AR application in the future and in other lessons and would recommend this application to their friends. This finding is also supported in the literature (Korucu et al., 2016; Özarslan, 2013; Taşkıran et al., 2015). Increasing the motivation of students (Delello, 2014; İbili & Şahin, 2013; Matcha & Rambli, 2013), being able to participate in the lesson actively (Abdüsselam & Karal, 2012; Bai et al., 2013; Cai et al., 2014; Delello, 2014; Taşkıran et al., 2015), interacting with the course content (Bai et al., 2013; Yusoff & Dahlan, 2013), and being a time-saving and practical tool (Özarslan, 2013) may have led students to want to use AR applications in the future and in other lessons.

Suggestions

Recommendations based on the research results

- Based on the research results, since the AR application positively affects students' academic achievement, course materials with AR technology can be used in appropriate courses and units.
- This study found that the use of AR applications has a significant positive effect on student motivation. Course materials enriched with AR technology should be designed to increase the motivation of students in different courses.
- Two-dimensional pictures prepared by the researcher were used as markers for running the AR application in the study. Three-dimensional models can be used as markers in future studies to increase concretization and relate to real life.
- A more realistic effect can be created on students by observing the three-dimensional models developed in this research using AR glasses.

Suggestions for future research

- This research was conducted with 7th-grade students for four weeks. The research can be carried out with students of different education levels and on a unit basis.
- Similar studies can be carried out in different learning areas of the Science course or different courses in the future.
- In addition to this study on students' academic achievement, motivation and opinions, attitude, cognitive load, etc. effects on AR can also be examined.
- This work, mostly aimed at individual learning, can be sustained with group learning and collaborative work.
- In addition to this study, which does not address research on students' demographic structures, further studies may focus on students with different characteristics (gender, age, learning style, etc.).

The findings of the study are limited to 54 7th-grade students. The AR experiences of the students in the experimental group are limited to the CellAR application developed by the researcher. The research conducted in the Science course is limited to 16 lesson hours for four weeks.

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