Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

Augmented Reality in 5th Grade Electricity Unit: Effects on Achievement, Motivation and Attitude

Hasan Hüseyin KUL[1]*, Asiye BERBER[2]

[1]Niğde Akşemseddin Bilim ve Sanat Merkezi, Niğde, Türkiye
[2]Faculty of Education, Eskişehir Osmangazi University, Eskişehir, Türkiye

*Corresponding author: hasanhuseyinkul@gmail.com

ABSTRACT This study aims to examine the effects of augmented reality (AR) in science courses. The study was conducted with 55 fifth grade students and a mixed method approach was adopted. An exploratory sequential design, a specific type of mixed-method design, was implemented in the research. In addition to various scales measuring academic achievement, motivation and attitudes towards science lessons, semi-structured interview forms were also used to understand students' perceptions of AR experiences. As a result of the study, no significant difference was found in terms of academic achievement between the experimental group, which was taught with AR supported science lessons, and the control group, which was taught with the traditional method. However, it was observed that the students who used AR had more positive attitudes towards science lessons and their motivation towards the lesson increased significantly. This shows that AR increases students' interest in science learning and enables them to participate more actively in the learning process. In conclusion, although augmented reality is not directly effective on academic achievement, it contributes positively to student motivation and attitude by enriching the learning environment.

Keywords Augmented reality, Science education, Academic achievement, Motivation, Electricity unit

1. INTRODUCTION

We live in an age where computers and the internet are an integral part of people's lives. Technology is an integral part of our daily lives. The growing interest in mobile devices and the availability of most services through digital applications clearly indicate a greater need for technology. It is clear that developed countries are the ones who can produce and adapt to changes and developments in the field of information technology the fastest. (Karakaş, & Özerbaş, 2020). This change has led to the use of information technologies becoming a central part of our lives (Sinan, & Yener, 2023). Organisations responsible for education and training must closely follow the technological changes and developments, and users must be taught how to use these technologies (Akkoyunlu, 1995). Educational environments must be harmonised with technology as a matter of course in countries' educational strategies. Developed countries invest heavily in integrating changing and developing technology into their education curricula (Durmuş, 2017). The students of our age, called digital natives, have fast access to information, adopt visuals and graphics instead of long texts, love games, and have the ability to do more than one job simultaneously. They different from previous generations (Bilgiç, Duman, & Seferoğlu, 2011) and educational institutions must integrate new technologies into educational environments while designing the teaching process.

Augmented reality (AR) technology is undeniably one of the innovations that can significantly enhance the integration of technology into education (Sayımer, & Küçüksaraç, 2015). AR serves as a powerful tool in creating authentic learning environments that accurately mirror real-world objects, contexts, and tasks (Moser, & Lewalter, 2024). Both AR and Virtual Reality (VR) have revolutionized educational approaches by providing immersive digital experiences, interactive settings, and simulations (Al-Ansi, Jaboob, Garad, & Al-Ansi, (2023). The 2006 Horizon Report identified AR as a promising technology, predicting its growing role in education (Johnson, Levine, Smith, & Stone, 2010).

Received: 10 April 2025
Revised: 11 June 2025
Published: 30 June 2025

AR technology is now applied across numerous educational disciplines. For example, it supports mathematics education (İbili, Çat, Resnyansky, Şahin, & Billinghurst, 2020), enhances physics education (Kavak, 2021; Abdusselam, 2014; Akçayır, Akçayır, Pektaş, & Ocak, 2016), and has demonstrated effectiveness in chemistry education (Cai, Chiang, Sun Lin, & Lee, 2017). In addition, Chen & Wang (2015) and Carrascosa, Ylardia, Paredes-Velasco, & García-Suelto (2024) highlighted AR's benefits in history education, while Kardoğan (2022) explored its applications in biology education. Its value has also been proven in social studies (Gümbür, 2019), language education (Tanrıverdi, 2022), engineering (Tiwari, Bhagat, & Lampropoulos, 2024), astronomy education (Sırakaya, 2015; Zhang, Sung, Hou, & Chang, 2014), and preschool education (Yılmaz, & Batdı, 2016).

Research on the use of augmented reality technology in the field of education has irrefutably demonstrated that the application yields positive results. The studies examined prove that augmented reality technology increases students' questioning capacity and question quality (İbili, & Şahin, 2013), creates reality perception in users (Eren, 2019), and is effective in reducing misconceptions (Fleck, & Simon, 2013; Sırakaya, 2015). It provides a learning environment independent of time and space (Wu, Lee, Chang, & Liang, 2013). It makes textbooks interesting (Çınar, 2017). It increases attention to the lesson (Özdemir, 2017). It appeals to multiple sensory organs (Koçak, Yılmaz, Küçük, & Göktaş, 2019). It makes abstract concepts concrete (Johnson, Levine, Smith, & Stone, 2010; Wu et al., 2013); it actively engages students in the lesson (Bacca, Baldiris, Fabregat, & Graf, (2015); it develops spatial skills (Wojciechowski, & Cellary, 2013); it makes lessons fun (Yılmaz, & Batdı, 2016); it increases academic achievement (Fidan, & Tuncel, 2019; Akkuş, 2021).

AR applications in education provide rich educational environments by visualising abstract concepts(Durak, & Yılmaz, 2019). Students typically transition from concrete to abstract thinking between the ages of 11 and 12 (Özmen, 2004). Some abstract concepts in science lessons make learning difficult during this period. Physics materials are considered complex, boring and abstract for students (Rizki et al., 2023). This study will determine the effect of using augmented reality in the 5th grade science curriculum on students' academic achievement, motivation, attitudes, and engagement with the material.

2. METHOD

In the study, a mixed method approach was used in which quantitative and qualitative methods were used together (Creswell, & Plano Clark, 2017). In this context, an explanatory sequential design, which is a special type of mixed method design, was applied. In this design, the first stage focuses on collecting and analysing quantitative data. Qualitative data are collected and analysed in the next stage in order to examine the findings obtained from quantitative data in more depth and to better understand their causes. The results of quantitative data are supported by the results obtained from qualitative data (Gültekin, Bayır, & Yaşar, 2020). This method and design was chosen for the research in order to determine whether the numerical answers given are supported by the results to be obtained from qualitative data. The fact that the age group is small due to the fact that the grade level in which the application is carried out is the fifth grade increases the possibility of making mistakes in the answers they will give in numerically coded scales.

Table 1 İmplementation dimension of the research

Method	Group	Before the implementation process	implementation process	After the implementation process
Quantitative Method	Experimental group	The science course academic achievement pre-test The motivation scale for learning science pre-test The augmented reality applications attitude scale pre-test	Science education with augmented reality applications	The science course academic achievement post-test The motivation scale for learning science post-test The augmented reality applications attitude scale post-test
	Control group	The science course academic achievement pre-test The motivation scale for learning science pre-test The augmented reality applications attitude scale pre-test	Science with tradiotional teaching techniques	The science course academic achievement post-test The motivation scale for learning science post-test The augmented reality applications attitude scale post-test
Qualitative Method	Experimental Group			The semi-structured interview form

2.1 Study Group

The research was conducted with 55 fifth-grade students selected using an appropriate sampling method. An appropriate sampling method can be defined as the researcher targeting the easiest elements to reach when creating a sample from the target population (Patton, 2005). Although the convenient sampling method is weaker than other sampling methods in terms of representing the population, the reason for this choice is that the study is long-term and the researcher's school was selected as the application school for observing the students. Twenty-nine students were in the experimental group and 26 students were in the control group. Simple random sampling was used to determine which group would be the experimental group and which would be the control group. In simple random sampling, each element of the group being studied has an equal chance of being selected. The sample to be included in the study is selected randomly from a list (Çepni, 2010). The following steps were taken to determine whether the groups were equivalent.

In terms of academic achievement, an independent samples t-test was conducted using the pre-test scores of the academic achievement test. The results of Levene's test indicated that the variances were homogeneously distributed, and no statistically significant difference was found between the experimental and control groups in terms of academic achievement ($p = 0.14$). Additionally, when the previous year's science course grade averages were considered, the group means were found to be quite similar (the mean score of the experimental group was 81.34, while the control group had a mean score of 80.79).

Similarly, an independent samples t-test was applied to the motivation toward science learning test. Levene's test again indicated homogeneity of variances, and no statistically significant difference was detected between the groups ($p = 0.82$). These results suggest that the experimental and control groups were homogeneous in terms of their motivation toward science learning. Overall, based on these findings, it can be concluded that the experimental and control groups in the study sample were homogeneous and did not differ significantly from each other prior to the intervention.

2.2 Data Collection Tools

The study employed four data collection tools:
The science course academic achievement test
The motivation scale for learning science
The augmented reality applications attitude scale
The semi-structured interview form is explained in turn.

The 'science academic achievement test' was used to determine whether augmented reality applications contribute to students' academic achievement. The "science learning motivation scale" was used to determine whether augmented reality applications create motivation in students to learn science. The 'augmented reality applications attitude scale' was used to determine students' attitudes toward the augmented reality applications they used, and the "semi-structured interview form" was used to determine students' opinions about both the process and the applications. The reason for using the identified forms is based on the assumption that the findings that can be obtained from the applications are related to academic achievement, motivation, attitude, and opinions.

The Academic Achievement Test was developed based on assessments prepared by the Ministry of National Education's General Directorate of Measurement, Evaluation, and Examination Services, with the required approvals in place. This test was administered to sixth-grade students. Item difficulty and discrimination indices were calculated, and unsuitable questions were removed, resulting in a final version consisting of twenty questions. Sixth graders were chosen because they had recently covered the relevant topics in their curriculum.

To assess any potential change in students' motivation toward science learning, the motivation scale by Dede and Yaman (2008) was utilized. This scale includes four sub-factors: motivation toward research, collaborative work, communication, and participation. It is a five-point Likert scale with an overall reliability coefficient of $\alpha=0.80$.

To evaluate students' attitudes toward AR applications, the AR Applications Attitude Scale, developed by Küçük, Yılmaz, Baydaş, and Göktaş (2014), was used. This scale contains three sub-factors: 'usage satisfaction,' 'usage anxiety,' and 'usage desire.' It is also a five-point Likert scale, with an overall reliability coefficient of $\alpha=0.84$.

For qualitative data collection, a semi-structured interview form was created by the researcher and reviewed by three subject matter experts. A review of the literature suggests that 2 to 5 expert opinions should be obtained for semi-structured interview forms (Büyüköztürk, Kılıç-Çakmak, Akgün, Karadeniz, & Demirel, 2015). Taking into account the experts' feedback and after two additional experts checked the grammar, the final interview form was implemented without any problems being observed.

2.3 Implementation process

The study was planned to last eight weeks using the AR Circuits mobile application. The suitability of the AR Circuits application for 5th grade lessons and learning outcomes was determined by consulting with subject matter experts. Prior to the application, science teachers were introduced to the AR Circuits application and conducted various experiments. After gaining experience with the application, three science teachers working at the same school reviewed the science textbook in use and selected the electricity unit based on the learning outcomes in the 5th grade science textbook, reaching a consensus.

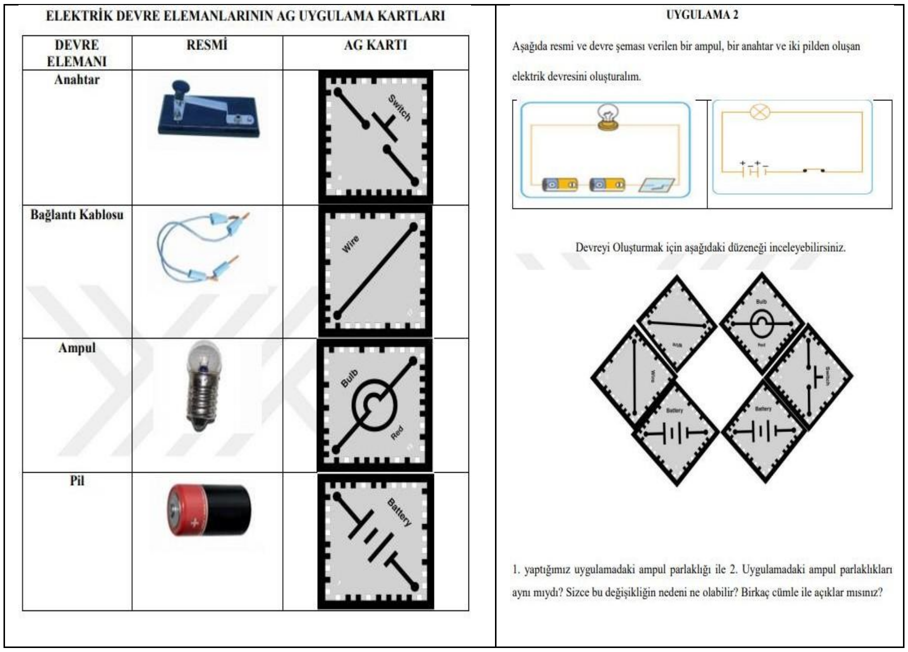

Figure 1 Sample pages from the work booklet

Before the application, an application sheet was prepared for the acquisitions and reproduced for the use of each student (Figure 1). In the sheet, there is theoretical information about the acquisitions and symbolized shapes of the sample electrical circuit elements to be used during the application. Application examples are given in Figure 1.

In Figure 2, examples of applications from the students' studies on electricity with mobile phones and AR cards are given.

2.4 Data Analyses

In this study, quantitative data collected during the research process were analyzed using the SPSS 24.0 package programme. The SPSS programme is a programme used to compare groups or show changes in measurements taken at different times within a group. In this study, the main focus was on determining the changes between groups and within groups before and after the application. Qualitative data underwent descriptive analysis. Prior to the quantitative data analysis, parametric tests were applied based on descriptive statistics and skewness and kurtosis values. Once it was confirmed that the data followed a normal distribution, independent and dependent t-tests, as well as mean and frequency analyses, were employed for pairwise comparisons. For qualitative data, descriptive analysis was used, suitable for data that does not require a deeper level of analysis (Yıldırım, & Şimşek, 2013). In analyzing qualitative data, each participant was coded as S1, S2, S3, and so on.

Figure 2 Sample pictures from the application

2.5 Ethical Approval

The authors were contacted via e-mail regarding the scales used in the study and the necessary permissions were obtained and used. The study group was formed with the permission of the Provincial Directorate of National Education of Kocaeli Governorship of the State of Turkey. For qualitative data, voluntary consent forms were obtained from the participants and permission documents were obtained from their parents.

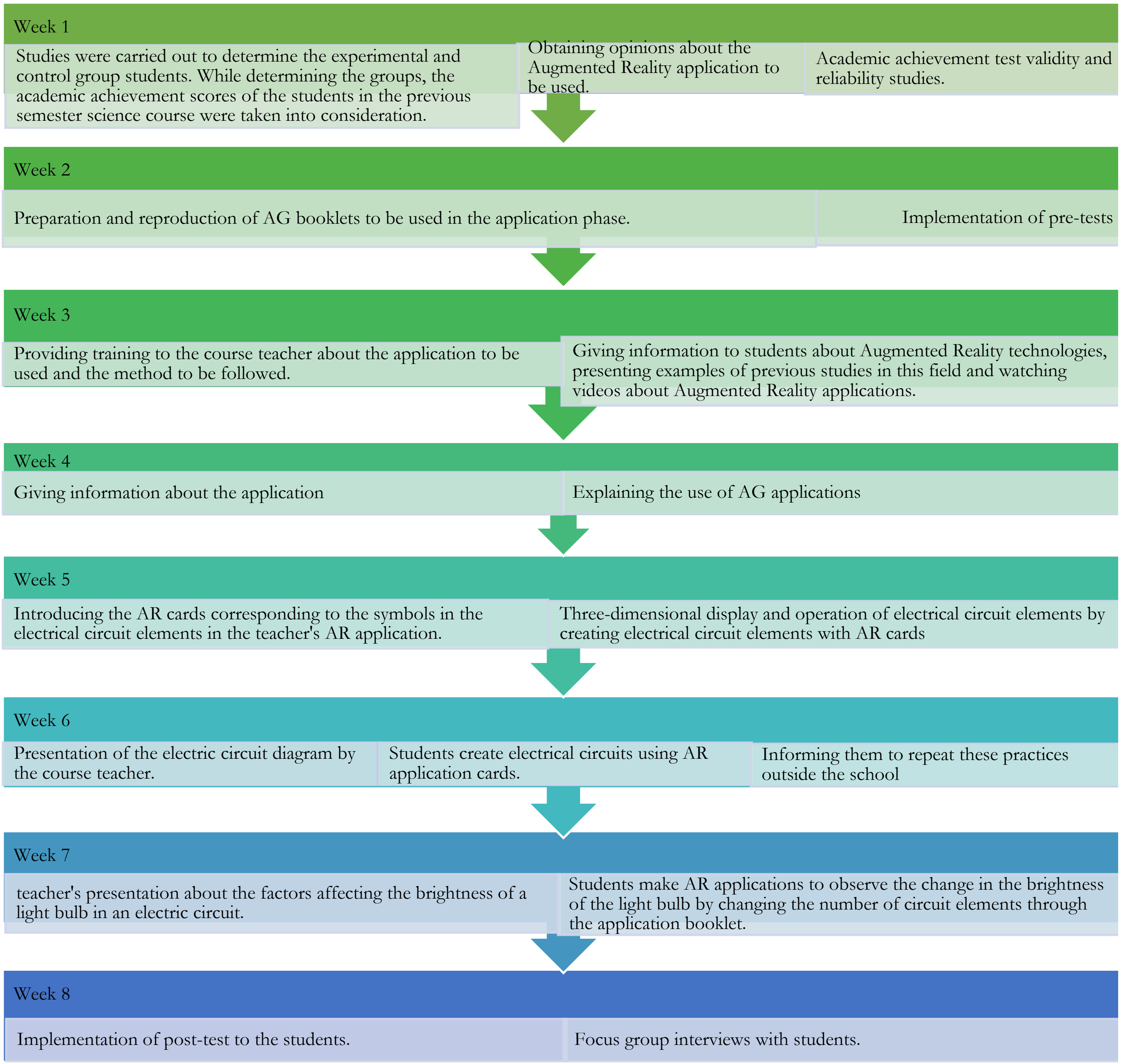

Figure 3 Eight-week implementation process stages

3. RESULTS AND DISCUSSION

3.1. Quantitative Results

In the results section obtained from quantitative data, students' achievement scores obtained from science course, their motivation to learn science course and their attitudes towards augmented reality applications were analysed. The results obtained are given in tables.

When Table 2 is examined, it is seen that there is no statistically significant difference between the mean pre-test academic achievement scores of the experimental and control groups. Although this difference is not statistically significant, it is seen that there is a greater increase in favor of the experimental group at the end of the application.

In examining table 3, no difference was identified in the pre-test academic achievement scores of the experimental group students based on gender. However, a statistically significant difference favoring female students was found in the post-test scores (*$p< 0.05$). For the control group, no difference was observed in the comparison of pre-test and post-test achievement scores by gender.

An analysis of the data in table 4 shows no difference between the groups in terms of motivation to learn science in the pre-test ($p=0.82>0.05$). However, at the end of the application process, a significant difference was observed in the post-test scores in favor of the experimental group.

When table 5 is examined, according to the data obtained from the augmented reality applications attitude scale applied to the experimental group students, the average of the answers given to the two positive factors of the scale was calculated as 4.56 for the "satisfaction of using" factor and 4.72 for the"desire touse" factor over five points. The mean score of the "anxiety of using" factor, which contains negative items, was 1.48.

Vilkoniene (2019), in a study on the digestive system with 110 seventh graders in science, found no difference between groups in academic achievement but noted a higher increase in the experimental group's average scores. Additional studies in the literature confirm that augmented reality often enhances academic achievement or at least yields statistically significant improvements (Akkiren, 2019; Çankaya & Girgin, 2018; Güngördü, 2018; Kırıkkaya & Şentürk, 2018; Wojciechowski & Cellary, 2013; Wu et al., 2013).

Table 2 Academic achievement test independent groups t-test results

			n	$\bar{X}$	Sd.	MeanRank	T	U	p
Academic Achievement Test	Pre Test	Experimental Group	29	0.20	0.07	25.03	-	291.0	0.14
		Control Group	26	0.23	0.08	-			
	Post Test	Experimental Group	29	0.75	0.17	-	1.97	-	0.05
		Control Group	26	0.66	0.16	-			

Table 3 Comparison of academic achievement test pre-test and post-test scores by gender.

		Sex	f	$\bar{X}$	Sd.	t	p
Experimental Group	Pre test	Female	14	0.20	0.07	0.540	0.59
		Male	15	0.19	0.06		
	Post test	Female	14	0.81	0.15	2.091	*0.04
		Male	15	0.69	0.17		
Control group	Pre-test	Female	14	0.24	0.07	0.903	0.38
		Male	12	0.21	0.08		
	Post test	Female	14	0.61	0.12	-1.800	0.08
		Male	12	0.72	0.18		

Table 4 Motivation scale for learning science course t-test results.

			n	$\bar{X}$	Sd.	Mean Rank	T	U	p
Motivation for Learning Science	Pre Test	Experimental Group	29	3.87	0.56	-	-0.23	-	0.82
		Control Group	26	3.90	0.29	-			
	Final Test	Experimental Group	29	4.65	0.15	-	-	132.00	0.00
		Control Group	26	4.43	0.39	18.58			

Table 5 Mean values of attitude scale towards AR applications

	N	Minimum	Maximum	Mean	Std.Deviation
Factor1: Satisfaction With Use	29	3.57	5.00	4.56	0.51
Factor2:Anxiety of Use*	29	1.00	3.67	1.48	0.72
Factor3:Willingness To Use	29	3.00	5.00	4.72	0.65
Scale Total	29	3.33	5.00	4.56	0.41

An analysis of the data from the academic achievement test revealed that the pre-test scores of both the experimental and control groups were similar, with no difference between them. However, post-test results indicated that the experimental group outperformed the control group, though this difference was not statistically significant. A similar study by Karakaş and Özerbaş (2020) found that while AR applications in high school Physics education increased academic achievement, they did not yield a significant difference between groups. In a five-week study by Çetintav (2023) with 8th-grade students in mathematics, AR technology significantly improved academic achievement in favor of the experimental group.

Motivation for learning science

The study identified a clear and significant difference in motivational outcomes between the experimental and control groups concerning science learning. It was concluded that using augmented reality applications has a powerful impact on students' motivation to learn science. In a similar study at the University of Cape Town, the use of AR in mobile applications was found to increase students' motivation, with specific motivational factors such as attention, satisfaction, and confidence showing marked improvement (Khan, Johnston & Ophoff, 2019). Sırakaya and Alsancak Sırakaya (2018) also provided strong evidence that seventh-grade students' motivation for learning science improved with AR use in their science course. In a study by Vate-U-Lan (2012) involving 484 students and AR-supported materials for language learning, results indicated that AR technology effectively fosters enthusiasm for learning English. A review of the literature reveals numerous studies that align with these findings, including those by Mahadzir & Phung (2013), Wei & Elias (2011), Billinghurst, Kato, & Poupyrev (2001), Bujak, Radu, Catrambone, MacIntyre, Zheng, & Golubski, (2013), Oh & Woo (2008), Wojciechowski & Cellary, Singhal, Bagga, Goyal, & Saxena (2012), Chiang et al. (2014), Furió, Juan, Segui, & Vivó (2015), Perez-Lopez & Contero (2013), and Solak & Cakir (2015).

Attitude towards AR applications

The research clearly showed that students developed positive attitudes towards AR applications. They expressed a high level of willingness to use and satisfaction with AR, while experiencing minimal anxiety about using it. It can be confidently concluded that students are generally pleased with AR applications. This finding is consistent with other studies in the literature. Atalay & Akgün (2020) definitively concluded that high school students have positive attitudes towards augmented reality (AR) applications. Moreover, their study revealed significant differences in attitudes towards AR based on gender, school type, and average daily internet usage. In their study on secondary school students' use of AR in education, Ramazanoğlu and Solak (2020) found that students' attitudes were positively affected and their opinions were favorable. Upon reviewing these studies, it is clear that AR applications have a positive impact on students' learning motivation and engagement, particularly in the experimental group (Cai, Chiang, Sun, Lin, & Lee, 2017).

3.2 Qualitative Results

The results obtained from the qualitative data of the research were analysed under two headings as positive and negative opinions on the use of AR applications (Figure 4).

When the data of the positive opinions of the students about the use of AR applications were analysed, it was seen that they increased academic achievement, created excitement, aroused a sense ofcuriosity, experienced a different experimental environment and offered a fun educational environment. Examples of these views are given below.

"Friends in another class learnt this subject by using cables and batteries. We used AG cards. It was easier to do it this way because it was difficult to connect the cables and so on, but I could do it easily with the cards."

"I think that teaching the electricity subject with AR application made me more successful."

"When I connected the LV cards to each other, the circuits were formed immediately and I could see whether the lamp was lit or not, it was easy for me to create the circuits in this way, I learnt better."

"I took the cards home and I was able to create these circuits myself at home, so learnt better". "I saw AR applications for the first time. It was very fun to do lessons with these applications."

"When I watched the video about AG for the first time in the lesson, I liked it very much, I wanted to do it right away, I think it would be very nice to teach the lessons in this way."

"I think it was very nice that our teacher made our lesson like this. We made electrical circuits with papers and telephones instead of wires. I saw something like this for the first time. When I pressed the keys, the lamps lit up, it was very fun and funny."

The students stated that they wanted AR applications to be applied both in different subjects in science and in other courses and that they wanted to use them by creating an environment that they could use continuously. Some student opinions on this subject are given below.

"I wish we could use Ar in other matters."

"Let it be done in every subject, not only in electricity, I would like to use it."

"My expectation from AR applications is that they should also work on the computer at school. So that we can always use it." (Figure 5)

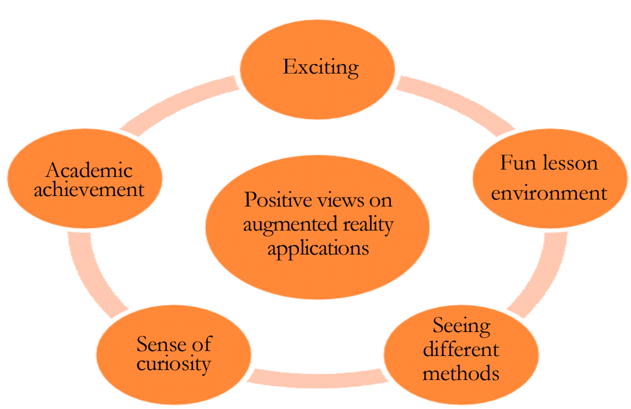

Figure 4 Positive views on the use of AR applications

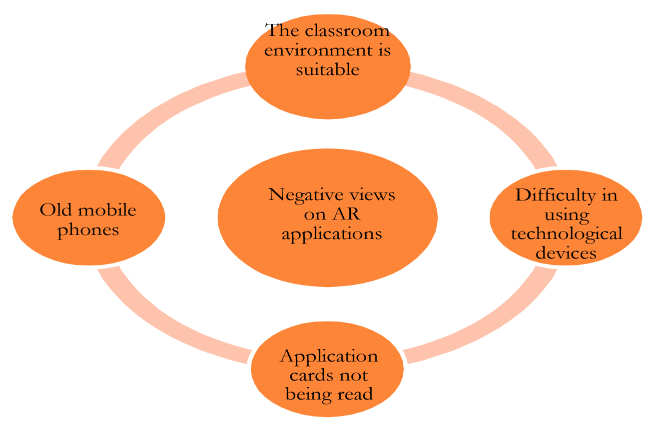

Figure 5 Students' negative views on the use of AR applications

While the students stated that they generally did not have any difficulty in using AR applications, they stated that they had problems such as the light in the application environment was a problem, their phones were old and the cards could not be read due to their technological devices. However, no difficulty was mentioned about the use of the AR application. In this context, sample statements of the students are given below.

"I didn't have any difficulty using the application. It comes to life immediately when you hold the phone. There is no other difficulty. It works immediately."

"Since our phone is a bit old, sometimes it had difficulty in reading the cards. Therefore, I had a little trouble."

"On the second day, because the classroom was a bit dark, it did not play the cards at first, but when I switched on the light, the images appeared. I had no other difficulties."

"I sometimes had difficulty in bringing the cards closer to each other to build a circuit. Sometimes my tablet did not read a few cards. It was like a disconnect there. But I was still able to do it."

"I would like to make one of these applications, but I don't know how to do it."

Students' positive views on the use of AR applications

The study found that students perceived lessons involving AR applications as fun, exciting, and engaging. They expressed clear satisfaction with using AR, highlighting that AR applications help make abstract concepts more tangible, with animating them in the three-dimensional real world being the best way to help students understand the subjects. A similar conclusion was reached in the study by Chai et al. (2017), which noted that "AR and motion sensing technology applications attracted interest" in secondary school physics courses focusing on the magnetic field. Küçük, Yılmaz, and Göktaş (2014) also found that AR applications created an effective learning environment by capturing students' attention, fostering positive attitudes towards AR, and boosting motivation for the course. These findings align with other studies, such as those by Mahadzir and Phung (2013), Vate-U-Lan (2012), and Wei and Elias (2011), which also support the positive impact of AR applications on student engagement and learning.

Students' negative views on the use of AR applications

Student views on AR applications clearly show that students have difficulties. This study confirms that the majority of students find the application straightforward to use, given the differences in learning styles. However, some students require further guidance on how to navigate the application. The literature clearly shows that one of the main difficulties with AR applications is that they are too complex for some students. These results are in line with those of this research. (Pan, Zheng, Xu, & Campbell, 2021). Another study found that students who initially found AR complex adapted easily and were able to apply it in a short time (Cai, Niu, Wen, & Li, 2021). Students will be able to make AR applications more easily if they encounter them more frequently. Another significant challenge faced by students in this study is the use of technology. Neri et al. (2024) were clear that the compatibility between the learning resource and the student's needs, goals and abilities is crucial in education. It also affects students' participation, motivation and learning outcomes. It is clear that the difficulty in using AR applications is due to the fact that certain skills are required. These include technology usage skills, spatial ability, problem solving and co-operation skills. If students lack these skills, they will develop a negative attitude towards AR applications (Kerawalla et al., 2006; Klopfer, & Squire, 2008; Wu et al., 2013).

4. CONCLUSION

This study concluded that augmented reality applications significantly increased students' academic achievement and motivation to learn science. Students' motivation scores were quite high for the augmented reality materials used. Integrating augmented reality into education is an effective way to facilitate and support learning through technology-enhanced content. This method improves the overall teaching and learning experience. However, to be successful with these methods, it is essential to adopt appropriate educational plans that take into account students' habits, knowledge, needs, personality traits and experiences (Lampropoulos, 2024). Augmented reality applications provide students with a rich, interactive learning environment thanks to their visual-based and three-dimensional technical features. At the same time, teachers can create an effective learning environment by using augmented reality applications effectively in the classroom. These technologies offer a flexible learning environment and contribute to the creation of students' own learning skills and control mechanisms (Özaltın, & Kahraman, 2023, p.21). Existing literature shows that augmented reality applications have a beneficial effect on students' attitudes and motivation towards learning (Di Serio, Ibanez, & Kloos, 2013). Küçük, Yılmaz, and Göktaş (2014) clearly showed that fifth grade secondary school students were willing to use AR and their concerns about using AR decreased as a result of the lessons taught with augmented reality applications. In addition, students expressed a clear desire to use such applications in other field courses. Similar results are observed in other studies (Chiang, Yang, & Hwang, 2014; Ibáñez, Di Serio, Villarána, & Kloos, 2014; İzgi Onbaşılı, 2018).

Other suggestions that can be given in future studies based on the results of this study are as follows. Paying attention to the adequate level of technological skills of the group in which the study will be carried out, high camera resolution of the technological devices to be used in the application and good processor speed can give better results. It is recommended that the light level of the classroom environment where the applications will be made should be sufficient. In addition, in order to prevent the confusion that may occur in the classroom in group studies, preparing the activities and applications and devices in advance will help the trainers in terms of time management.

The usability and advantages of AR applications in education will develop over time with the opportunities offered by constantly changing and developing technology designs. Field studies can contribute to the literature by providing more insights as the experiences of learners increase and by analysing the ergonomic and hardware features of the technology to be used in augmented reality-based learning environments.

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