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The Effect of Mathematics Teaching with Mobile Augmented Reality Technology on Secondary School Students' Attitudes and Academic Achievements

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Nowadays, the prevalence of augmented reality technology is increasing day by day, along with the benefits it provides in many fields from shopping to education, from medicine to the automotive sector. This technology, which allows the real environment to interact with the virtual environment, has been used in many studies in the literature. In this research, the seventh-grade mathematics course, which was processed with augmented reality applications, was conducted. The effects of classroom students' academic achievements, attitudes toward mathematics lessons, and augmented reality applications were examined. For this purpose, a quasi-experimental design with a pre-test, and post-test control group was used. The research was conducted with a total of 60 students, including 30 in the experimental group and 30 in the control group. A total of 10 lesson hours were applied, including 5 hours per week. Among the quantitative data collection tools, achievement tests, mathematics attitude scales, and augmented reality applications attitude scales were used in the research. As a result of the research, it was found that the course conducted with augmented reality application has a positive effect on the academic achievements of students. However, it was found that there was no significant difference in their attitudes towards mathematics courses. The written opinions received from the students show that the students find the lesson more entertaining and want to use it in other lessons as well.

Introduction

Developments in information and communication technologies have been changing our lives in recent years. Mobile devices are widely used by new generations no matter their age (Tomi & Rambli, 2013). In this way, the interactive learning environments obtained in this way can turn passive students into active students (Moore, Fowler, & Watson, 2007). In addition,

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involving students in the learning process and ensuring that they are effective in the process provides effective learning. Thus, educators are aiming to go beyond traditional educational environments and use multimedia technologies to teach complex subjects more entertainingly (Yetişir, 2019). With the digitalization in society, the virtual environment and the physical environment have been integrated; virtual reality, augmented reality, and mixed reality applications have started to be used in society (Turhan, Metin & Çevik, 2022). Augmented reality technology, which distinguishes virtual reality from its dependence on the virtual environment and allows the virtual environment to be viewed together, is used in many fields such as journalism, medicine, education, chemistry, physics, astrology (Medina, Chen, & Weghorst, 2008), computer, tourism, industry, decoration, automotive (Turhan, Metin & Çevik, 2022). For example; it is used in the automotive sector by many companies such as BMW, Volkswagen in the design, maintenance, assembly, and crash tests of the vehicle (Sünger, 2019). In cases such as natural disasters and nuclear accidents, an AR-based (Augmented Reality) mobile guide was used to obtain information such as the name and distance of the shelter, and how many people there are in the shelter (Içten and Bal, 2017).

When the literature about the use of augmented reality is examined, it is stated that it has many contributions to education and has gained a different dimension (Talan, 2021). AR the bodily experiences – including cultural, contextual, and social factors – which we engage with when we use AR help us to construct meanings from our reality (FitzGerald, Ferguson, Adams, & Gaved, 2013). For example, AR allows the creation of difficult-to-create environments in an educational environment decisively in a more cost-effective way. It provides visualization of abstract subjects to facilitate understanding and creates a strengthening effect on long-term memory (Schutera, et al., 2021). It facilitates the successful implementation of dangerous applications to be performed by students in an educational environment in a virtual environment and encourages and supports students' social skills (Cahyono et al., 2020). In 2017, it was determined that the student's achievements were significantly higher with the material developed by Gül and Şahin for computer hardware teaching (Gül and Sahin, 2017). In a study by Liu and colleagues in 2019, it is stated that AR has a positive effect on students' learning performance and attitudes in mathematics. Creating 3D models in mathematics learning also helps to create a virtual space, collaborative learning, and visualize operations and objects that cannot be viewed. Considering the benefits mentioned as the Twenty-First Century attempted to teach the skills in the skills of constructivist learning, where augmented reality and game-based and inquiry-based learning support methods, it is seen (Bower et al., 2014). For students to acquire the relevant skills, various interactive applications are carried out in the lessons. Since the mathematics course itself is abstract, concretization is carried out in the lessons and it is tried to be concretized with examples from real life. Mobile augmented reality applications are contributing to this effort. In studies on the use of augmented reality in mathematics education, it has been observed that studies have been conducted with applications prepared by a one-time researcher, usually prepared with Vuforia and Unity programs. Unity3D software was used in the research in which augmented reality activities were prepared for the acquisitions related to the fractions subject of the 5th-grade mathematics course (Özdemir & Özçakır, 2019). In another study, it is stated that augmented reality-supported materials prepared for computer hardware teaching were produced using Vuforia and Unity3D software (Gül & Şahin, 2017). AnakartAR application, which shows computer programming students how to assemble a motherboard, was developed by the researcher using Unity 3D software (Sırakaya, 2016). However, in the digital age, it is crucial for the course teacher to prepare an application on his own and know that he can use the application when preparing materials on different topics in the future. There is more than one application used for this purpose. For example, some applications also have ready-made content for certain topics.

However, their languages may be different and the content that should be according to the student level may need to change. When the related literature is examined, augmented reality environments are created from scratch with software such as Unity 3D, Vuforia, Aurasma, ARtoolKit, Blender (İçten & Bal, 2017). However, since everything is progressing rapidly in the digital age, teaching materials should also be prepared quickly and teachers should be able to create their materials without the need for a programmer. This study differs from other studies in that it uses an augmented reality application free of charge that enables mathematics lessons to be carried out with an application that can be used effectively with basic computer skills. The augmented reality material, which has not been used in any previous study, can be created free of charge with the mobile application, and the material can be created by preparing existing templates or recreated templates. In this context, seventh-grade math lessons on algebra on the topic of mobile devices (smartphones and tablets) for free on "Assemblr Edu" by using an augmented reality application that allows the preparation of students' academic achievement and attitudes were examined and interpreted the data obtained made suggestions.

Method

Research Design

In the research, which was conducted to determine the attitudes of secondary school students towards augmented reality applications in mathematics lessons and to determine the effect of Augmented Reality Applications on their achievement and attitudes towards Mathematics course, a randomized semi-experimental design was used from quantitative research methods. Experimental design was preferred because the researcher aims to measure variables and test the cause and effect relationship between these variables (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2015). In the research, the experimental and control groups were determined by random assignment method (lottery). Thus, the research model was determined as a semi-experimental design with pretest-posttest control group. In line with this design, in the fall semester of the 2022-2023 academic year, a total of 10 hours of lessons, 5 hours per week, were held with 30 class A and 30 class B students in a secondary school in Tuzla, Istanbul, affiliated to the Ministry of National Education. For this purpose, first of all, the necessary ethical permissions were obtained.

Data Analysis

The data collected in the direction of the study's aims were analyzed using SPSS 26 statistical calculation software. In this direction, arithmetic mean, independent, and dependent sample t-tests were used in accordance with the sub-objectives of the research. Firstly, it was analyzed whether the experimental and control groups were equivalent in terms of achievement. As a result of the independent sample t-test, it was found that there was no statistically significant difference between the two groups; in other words, the groups were equivalent (t=,135; p>,05). After the result was obtained, a dependent sample t-test was applied to determine whether the post-test and pre-test scores of the control and experimental groups of the algebraic expressions academic achievement test, the attitudes towards mathematics course, and the attitude scale towards augmented reality applications were significantly different within their groups. Independent sample t-test was applied to determine whether the post-test and pre-test scores of the algebraic expressions academic achievement test and the attitude scale towards mathematics course were significantly different between the groups and the results were interpreted in the findings section.

Table 1. Detailed information within the scope of the research method

	Pre-test	**Process**	**Post-test**
Experimental Group	Algebraic Expressions Success Test Augmented Reality Applications Attitude Scale The Mathematics Attitude Scale	Processing of the course with the prepared Augmented Reality Applications	Algebraic Expressions Success Test Augmented Reality Applications Attitude Scale The Mathematics Attitude Scale
Control Group	Algebraic Expressions Success Test The Mathematics Attitude Scale	Processing with the process determined by the Ministry of National Education in accordance with the curriculum	Algebraic Expressions Success Test The Mathematics Attitude Scale

Within the scope of the research model, experimental and control groups were formed from seventh-grade students and a pre-test was applied to the experimental and control group. 10-hour lesson plans were created for the experimental group and the lesson was processed with Augmented Reality Applications. While the lesson was processed with the Augmented Reality Application with the experimental group, 10 hour study was conducted with the control group by applying the method appropriate to the Ministry of Education curriculum. To determine the direction of the change in attitude to Mathematics lesson after the application, the "Mathematics Attitude Scale" was applied to the experimental and control group as the final test. In addition, the "Augmented Reality Applications Attitude Scale" was applied to the experimental group, and the scale was not applied to the control group because no applications for augmented reality applications were made, and assuming that the control group students had knowledge deficiencies related to AR applications. Detailed information about the research method is summarized in Table 1.

Sample

The sample of the study consisted of 60 students, 31 female, and 29 male, with similar mathematics achievement, studying in the seventh grade in a secondary school in the Tuzla district of Istanbul province in the 2022-2023 academic year. The students studying in the Class A branch were determined as the experimental group and the students studying in Class B were determined as the control group.

Data Collection Tools

In this study, the algebraic expressions achievement test developed by Okuducu (2020), the attitude scale for augmented reality applications developed by Küçük, Yılmaz, Baydaş and Göktaş (2014), and the mathematics attitude scale developed by Önal (2013) were used to collect quantitative data after obtaining the necessary permissions. Detailed information about these scales used within the scope of the research is given below.

Achievement Test

In the study, the academic achievement test developed by Okuducu (2020) initially consisted of 30 questions. The pilot application was carried out with 150 seventh-grade students. As a result of the pilot application, three items were removed from the test because their discrimination was below 0.20. Since the discrimination of four items was between 0.20 and 0.40, the range items were revised, necessary corrections were made and the final version of the test consisting of 27 questions was given (Okuducu, 2020).

Augmented Reality Opinion Scale

In the research, a 15-item three-factor 5-Likert type scale developed by Küçük et al. (2014) was used to determine attitudes towards activities prepared with AR for the topic of 'algebraic expressions'. Exploratory factor analysis and confirmatory factor analysis were performed by the developer to ensure the structural validity of the scale. In the first-factor analysis results, 26 items were collected under five factors in the scale, the items under two or more factors were examined according to their requirements and were assigned one by one according to the fact that they were less necessary. In this direction, since the Cronbach α coefficient of the scale was α=. 420 and the reliability of the scale decreased to α=.690, two items under this factor were removed from the scale. Finally, the scale was collected under three factors and consisted of 15 items (Küçük et al., 2014). In the final version of the scale, the internal reliability coefficient α=0.835 was found as a result of Cronbach alpha analysis.

Math Attitude Scale

In the research, a 22-item four-factor 5-point Likert-type scale was used to determine the attitude towards mathematics prepared with AR for the topic 'algebraic expressions'. The attitude scale towards mathematics developed by Önal (2013) consists of "interest", "anxiety", "work" and "necessity" factors. The scale items are of the 5 point Likert type and are as follows: "I Completely Agree", "I Agree", "I am undecided", "I Disagree" and "I Strongly Disagree". The internal consistency coefficient for the whole scale (Cronbach's alpha coefficient) .90 has been found. The factors that make up the internal consistency coefficient of the scale (Cronbach's Alpha coefficient) respectively "Interest" for 0,89 (Article 10), "Anxiety" is 0.74 (Article 5), "work" is 0,69 (Article 4), "Necessity" for 0,70 (article number 3). At the same time, it was confirmed that the scale forms a four-factor structure with confirmatory factor analysis (Önal, 2013). The internal consistency coefficient (Cronbach's alpha coefficient) of the whole scale was found to be 0.90.

Research Process and Augmented Reality Learning Material

Within the scope of the study, the Assemblr Edu application was used to prepare the related augmented reality applications. During the application selection phase, the Play Store application was searched for augmented reality applications that can be used in mathematics with various words and the applications were tried one by one. The reason for choosing this application is that it allows the user to design materials suitable for their purposes. Applications such as Vuforia, Unity 3D, Alive, Layar, and Wikitude also allow the user to prepare materials, but require the user to have more knowledge about coding or drawing in these programs. However, it can be said that the Assemblr Edu application is more practical because it can be easily used by downloading it from Play Store or App Store to mobile phones or tablets. Assemblr Edu application can be easily used on Android and iOS operating systems. The program works in the browser on desktop computers. After registering with a Google account, various ready-made examples from the fields of computer science, physics, geometry, chemistry, geography, history, astronomy, physical education, social sciences, biology, English and mathematics can be used from the "Topics" section on the screen shown in Figure 1.

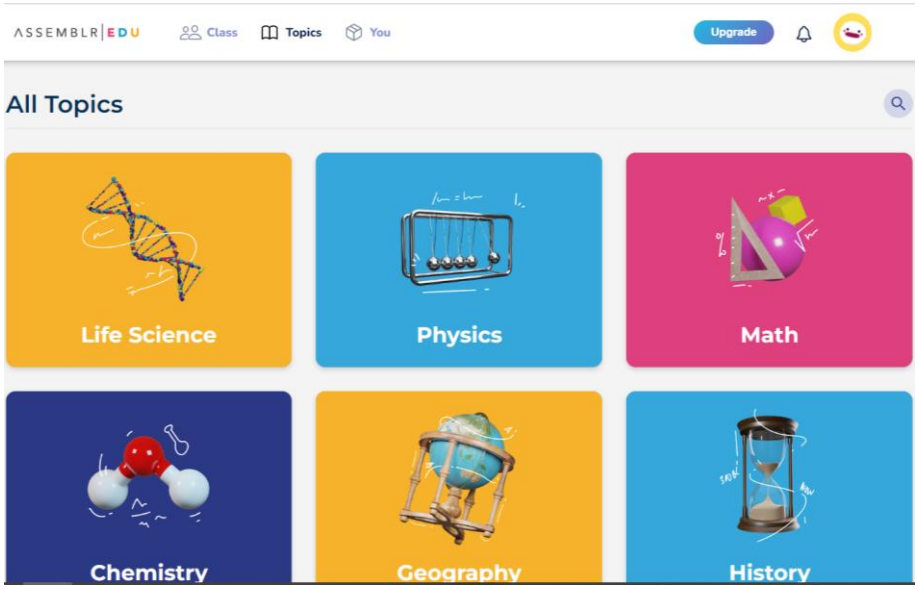

Figure 1: Assemblr Edu application "Topics" menu

If we want to prepare our application, some characters or environments are missing in the free version, but usually many interactive applications can be prepared. For this purpose, by clicking on the "Your Project" tab, and selecting "Create Your Creation", an existing template or an empty page can be opened, as shown in Figure 2, and the material preparation process can be started.

Figure 2: Assemblr Edu application "Create Your Project" tab

For the material to be used after preparation if desired, a certain marker can be determined by a person, the frame code can be downloaded, or it can be used by placing it wherever the screen is held. The application has monthly or annual basic and premium packages.

As shown in Figure 3, users can access the AR application related to the topic of algebraic expressions developed by the researcher from their mobile phones or tablets by reading the square code generated by the Assemblr Edu. For this operation, it is necessary to have a barcode reader on mobile devices. The materials used in this AR application developed with Assemblr Edu have been prepared in 3 groups.

Figure 3: The square code generated by the program for the augmented reality application prepared with Assemblr Edu

Students "perform processing algebraic expressions addition and subtraction," and "natural algebraic expression multiplies with a number to an" a change in behavior to create gains for first 10 questions for the previous information to write the algebraic expression to remind of the material, which consists of the input screen, and as an example, a question screen is seen in Figure 4.

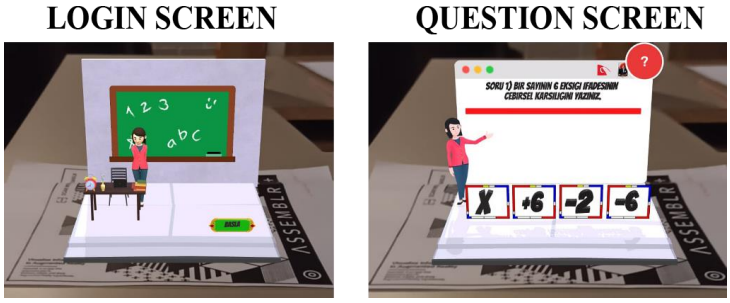

Figure 4: Introduction and question screen of the augmented reality application prepared with Assemblr Edu

Students can create the correct answer to the question seen on the screen by clicking on the correct ones of the given expressions. When the wrong one is clicked, the wrong sound is emitted and it is not allowed to move. When the correct expression is clicked, the correct sound and the next button appear on the screen as in Figure 5.

Figure 5: The answer page of the augmented reality application prepared with Assemblr Edu

A sample screen of the material prepared for students to learn addition and subtraction operations with algebra tiles in accordance with the acquisition of algebraic expressions after attracting their interest and reminding their prior knowledge is shown in Figure 6.

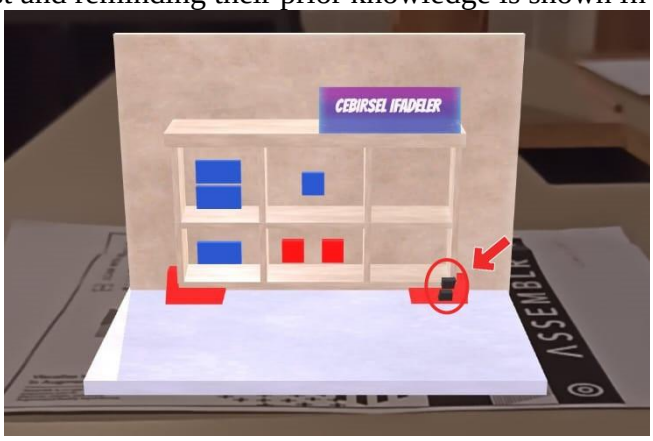

Figure 6: Algebra tiles sample expression screen of the augmented reality application prepared with Assemblr Edu

During the lesson, the teacher explained the meanings of the blue rectangle, blue square, and red square to the students, and then, in the augmented reality application, the blue and red tiles seen in Figure 6 correspond to the equal sign shown with the arrow at the bottom right, the screenshot seen in Figure 7 appears in an animated form.

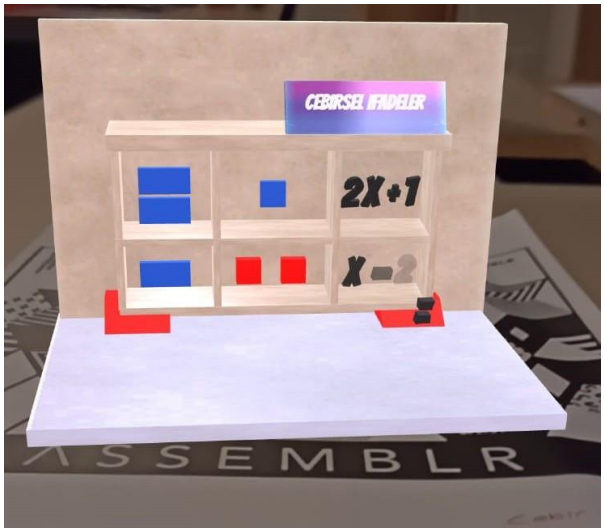

Figure 7: Algebra tiles sample animated screen of the augmented reality application prepared with Assemblr Edu

Following the application of the 12 algebra tile expression, the student is questioned on the procedures of multiplying an algebraic expression by a natural number and addition-subtraction in algebraic expressions. In Figure 8, the sample question screen is displayed.

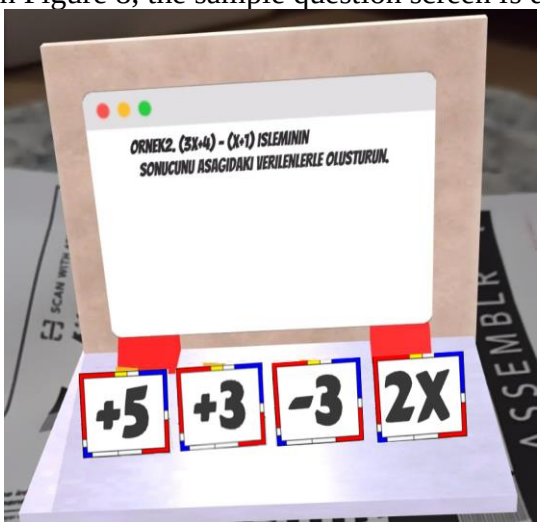

Figure 8: Addition-subtraction sample question screen with algebra tiles belonging to the augmented reality application prepared with Assemblr Edu

The screen that appears in Figure 8 is formed when the correct options are marked by the student when the answer to the question, an example of which is seen in Figure 9, is selected.

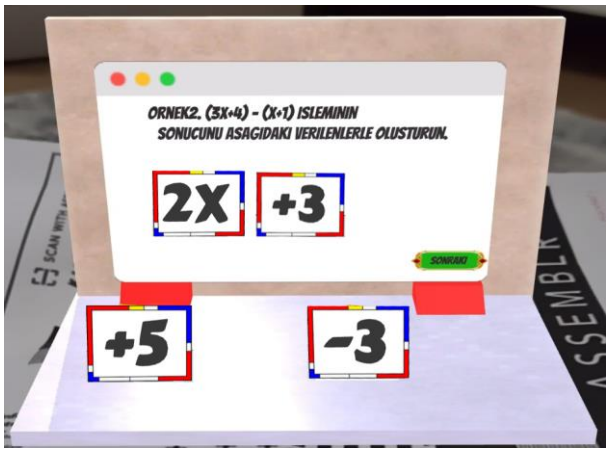

Figure 9: Addition-subtraction sample answer screen with algebra tiles belonging to the augmented reality application prepared with Assemblr Edu

After the operations of addition and subtraction with algebraic expressions and multiplication of algebraic expressions with a natural number were taught here, the let's test ourselves activity with 10 questions was applied last in the lesson. The login screenshot of the related activity is shown in Figure 10.

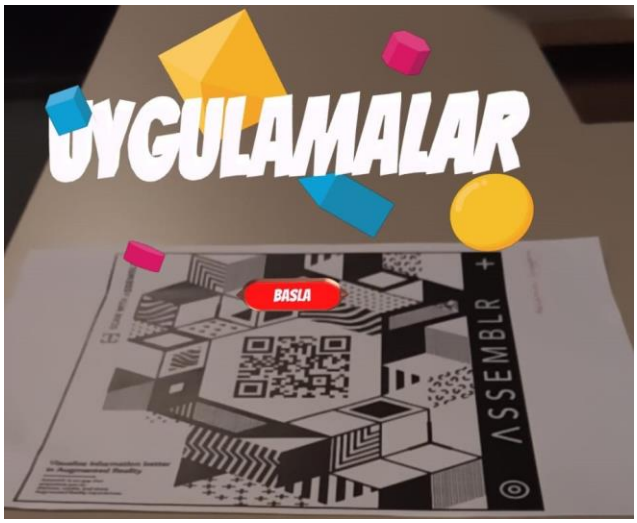

Figure 10: Let's test ourselves screen of the augmented reality application prepared with Assemblr Edu

Applause can be heard and Figure 11 can be seen on the screen when the questions are answered correctly.

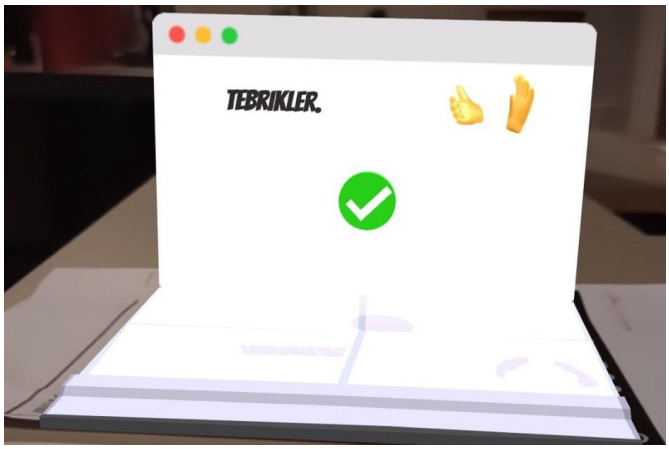

Figure 11: The correct answer screen of the augmented reality application prepared with Assemblr Edu

Figure 12 and the incorrect sound play when the incorrect response is entered.

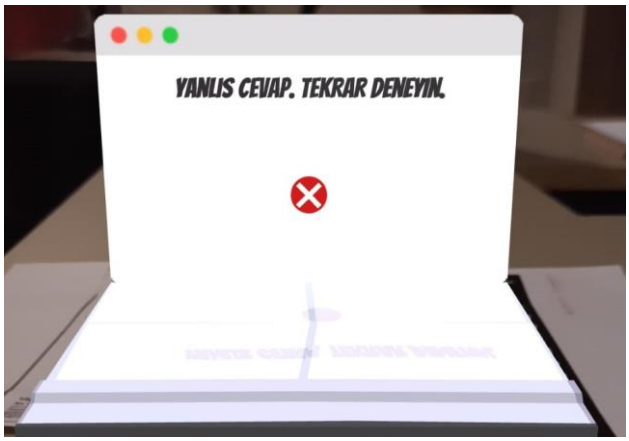

Figure 12: The wrong answer screen of the augmented reality application prepared with Assemblr Edu

The images of the application in the classroom are given in Figure 13. Teaching a lesson with augmented reality applications was a source of motivation for the students. They stated that doing activities as a group in the classroom was exciting for them. Although the Assemblr Edu application does not give Turkish character error when viewed in 3D, as can be understood from the pictures, it gives Turkish character error when the augmented reality output is displayed. This error has not been fixed in the Premium version of the application.
The images in which the application is performed in the classroom are given in Figure 13. Processing lessons with augmented reality applications has been a source of motivation for students. They expressed that it was exciting for them to do activities in the classroom as a group. Turkish character error is displayed as augmented reality, although Assemblr Edu application does not give Turkish character error when displayed in 3D form, as can be understood from the pictures when viewed by the application, it gives Turkish character error when displayed as augmented reality. This error was also not resolved in the Premium version of the application.

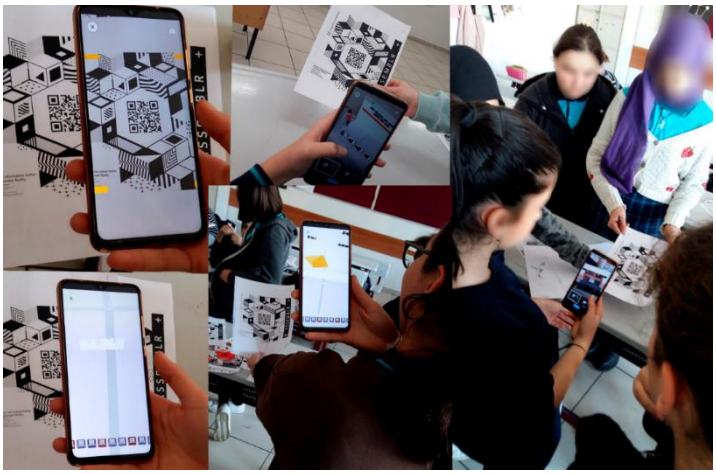

Figure 13: Images of the lesson processed using Assemblr Edu augmented reality application with the students of the experimental group

Findings

The first objective, "Is there a significant difference between the pre-test academic achievement scores of the "algebraic expressions" course taught to the control group and the experimental group students using mobile augmented reality application?" was sought to be answered. For this purpose, the normal distribution of the achievement test was examined and it was determined that there was no statistically significant difference (p >.05). The results obtained are shown in table 2.

Table 2. The Results of the Independent Sample T-Test Related to the Algebraic Expressions Pretest Scores of the Experimental and Control Group Student

	Group	N	$\bar{x}$	S	t	p
Pre-test	Experiment	30	41,27	20,172	,135	,893
	Control	30	40,57	20,063		

As a result of the pre-test scores obtained according to Table 2, the average pre-test scores of the control and experimental groups were found to be 41.27 and 40.57, respectively. As a result of the independent sample t-test, there were no statistical differences between these two groups (t=,135; p>,05). This situation supports that the control and experimental group pre-test score averages are not statistically different from each other.

The second sub-objective, "Does the change between the algebraic expressions pre-test and post-test scores of the experimental and control group students show a significant difference?" was sought to be answered.

As obtained when deciphering whether there is a significant difference between the post-test and pre-test scores of the experimental and control group.

Table 3. The Results of the Independent Sample T-Test Related to the Algebraic Expressions Difference Scores of the Experimental and Control Group Students

	Group	N	$\bar{x}$	S	t	p
Difference	Experiment	30	21,26	23,68	2,86	,006
	Control	30	5,26	19,37		

According to Table 3, the pre-test-post-test difference averages of the experimental and control groups were found to be 21.26 and 5.26, respectively. As a result of the independent sample t-test, a statistical difference was found between these two groups (t=2.86, p<,05). This situation supports that the experimental and control group pre-test- post-test difference averages are statistically different from each other. This difference is in favour of the experimental group.
The third sub-objective, "Is there a significant difference between the mean achievement pre-test and post-test scores of the experimental group students?" was sought to be answered.

Table 4. The Results of the Related Sample T-Test Related to the Pre-Test/Post test Scores of Algebraic Expressions of the Experimental Group Students

	Test	N	$\bar{x}$	S	t	p
Experiment	Pre-test	30	41,27	20,17	3,10	,003
	Post-test	30	62,53	21,05		

According to Table 4, the mean pre-test score of the experimental group was found to be 41.27 and the mean post-test score was found to be 62.53. As a result of the paired sample t-test, there is a significant difference between the pretest-posttest scores of the experimental group in favor of the post-test. T=3,10, p=,003.
The answer to the fourth sub-objective, "Is there a significant difference between the mean post-test academic achievement scores of the experimental group students and the control group students on the subject of "algebraic expressions" taught using mobile augmented reality application?" was sought.

Table 5. The Results of the Experimental and Control Group Students on Algebraic Expressions Post-Test Score Averages

	Test	N	$\bar{x}$	S	t	p
Post-test	Experiment	30	62,53	21,05	3,10	,003
	Control	30	45,83	20,67		

When Table 5 is examined, it is seen that the average post-test scores of the groups were 62.53 and 45.83, respectively. As a result of the test, there is a significant difference between the deficiency averages of the experimental and control groups in favor of the experimental group.
The answer to the fifth sub-objective, "Is there a significant difference between the pre-test and post-test mean scores of the control group students?" was sought.

Table 6. The Results of the Control Group Students Regarding the Difference in Achievement Pre-Test/Post-Test Score Averages

	Test	N	$\bar{x}$	S	T	p
Control	Pre-test	30	40,57	20,06	3,10	,893
	Post-test	30	45,83	20,67		

According to Table 6, the difference between the mean scores of the control group was found to be 45.83-40.57=5.26. According to the value obtained as a result of the test, there is no significant difference. However, the mean pretest-posttest score difference of the experimental group was calculated as 21.26 and the difference was found to be more significant.

The sixth sub-objective, "Does the augmented reality application via mobile devices affect the attitudes of the students in the experimental group towards augmented reality applications?" was sought to be answered. For this purpose, firstly, the normality test was performed on the Attitude Scale of Augmented Reality Applications, the decoupling and kurtosis coefficients were examined and it was seen that these coefficients were between +1.5 and -1.5. Thus, it was found that the scale showed a normal distribution. After it was determined that the scale had a normal distribution, the dependent sample t-test (Paired Samples Statistics) was performed, which appears in Table 7.

Table 7. The Results of the Experimental Group Students on the Difference between The Augmented Reality Applications Attitude Scale Pre-Test and Post-Test

	Test	N	$\bar{x}$	S	T	p
Experiment	Pre-test	30	2,95	,41	-2,02	,052
	Post-test	30	3,20	,32		

When Table 7 is analyzed, it is seen that the pre-test mean of the experimental group was calculated as 2.95 and the post-test mean was calculated as 3.20. Accordingly, there was a small increase, albeit in the positive direction, in the attitude scores of the experimental group students towards augmented reality. However, there is no significant difference.

The seventh sub-objective of the study, "Does augmented reality application through mobile devices have an effect on the attitudes of the students in the experimental group towards mathematics?" was sought to be answered. For this purpose, firstly, it was determined that the scale distribution was normal. Then, the dependent sample t-test (Paired Samples Statistics) in Table 7 was applied.

Table 8. The Results of the Students of the Experimental Group regarding the Difference in the Mean Scores of the Mathematics attitude scale Pre-Test-Post-Test

	Test	N	$\bar{x}$	S	T	p
Experimental	Pre-test	30	3,67	,62	1,57	,126
	Post-test	30	3,44	,53		

Deciphering Table 8, it is observed that there is no significant difference between the pre-test-post-test mathematics attitudes of the students of the experimental group (p>,05).

Conclusion and Recommendations

Algebraic expressions have an important place in the secondary school mathematics curriculum. The acquisitions related to the algebra learning area are first included in the 6th-grade level. As a result of the analyses made in the examination of the effect of augmented reality on the academic achievement and attitudes of algebra students while using augmented reality area in learning mathematics, it was concluded that the experimental group students were significantly successful and the control group students were positively successful. There was no significant difference between the groups according to the pre-test scores of the knowledge of algebraic expressions given to the experimental and control group students before the application. This situation shows that the prior knowledge of the students distributed to the two groups in an unbiased way is equivalent to each other. This equivalence provides a clearer and more meaningful interpretation of the AR application material used in the research process. After the application, a post-test was applied to the experimental group in which the course was taught using the AR application, and to the control group in which the course was taught with the traditional course material. According to the data obtained, a significant difference was

found between the pre-test and post-test scores of the students in both groups. According to these results, it was determined that the teaching methods used in both groups made a significant contribution to the academic achievement of the students, but this contribution was higher in the teaching method using augmented reality. According to the post-test analyses between the groups, there is a significant difference between the two groups. According to these results, it can be said that the AR application developed for the experimental group was effective enough to create a significant difference from the lessons conducted with classical methods. It is evident that pupils have the chance to participate actively in the sessions when they are taught using augmented reality. Therefore, students taking an active role in the lesson can enable the teacher to ask more questions and provide a better understanding of the subject.

Although experimental studies have been conducted to determine the effects of AR applications in mathematics education, when the studies have been examined, it has been found that qualitative studies have generally been conducted and the number of experimental studies is insufficient (Palancı & Turan, 2021). It has been seen that the findings of this research are similar in terms of the encouragement (Nincarean, Ali, Halim, & Rahman, 2013) and positive contribution of the studies conducted on the use of augmented reality in the literature to the student's learning process and their achievements. For example; Özdemir and Özçakır (2019) stated in their studies that teaching fractions with augmented reality support positively affects their attitudes towards mathematics with success scores related to fractions. It has been concluded that the environments created with AR contain animation and videos, which are more effective in increasing students' interest in the lesson and collecting their attention, as they give a sense of reality (Gül & Şahin, 2017). Özaydın Aydoğdu and Eryılmaz (2019) mentioned in their study that AR applications increase success in education, facilitate learning, eliminate misconceptions and increase retention in learning benefits (Aydoğdu & Eryılmaz, 2019). In a study conducted on the achievements of learning algebraic equations in Malaysia, it was concluded that processing lessons with mobile augmented reality applications significantly increases student achievement (Saundarajan, Osman, Daud, Abu, & Pairan, 2020). In another study conducted in Malaysia, the PrismAR application was developed for use in the subject of "prism" and it was found that it can be a successful method for increasing students' achievement in mathematics (Ahmad & Junaini, 2022). In addition, the findings obtained on the attitudes of the students are similar to the interpretation of Saundarajan, Osman, Daud, Abu, & Pairan (2020) that the attitudes of the students towards practice in the course processed with augmented reality are still at an intermediate level. Another finding is; that learners who used mobile AR had higher motivation, better performance, and less anxiety than those who did not use mobile AR (Chen, 2019). Apart from, although AR tools are easy to use, it is stated that it takes time to send the image, decipher the text, and reflect the meaning of the text (Saidin, Halim, & Yahaya, 2015). The most common problems in the studies carried out are; not every student has a mobile device or the mobile device used does not support the application, the AR application requires a long time to develop from scratch (Masneri, Domínguez, Zorrilla, Larrañaga, & Arruarte, 2022), spending more time using it, and a limited number of applications have Turkish language support (Hazneci, 2019). In this study, no technical problems were encountered during the application process. Only the lack of Turkish language support of Assemblr Edu application while developing AR material can be considered as a disadvantage.

As a result, it is thought that this study has made an important contribution in terms of revealing that the use of augmented reality applications in teaching processes has a significant impact on students' academic achievements.

Recommendations

In line with the results of the research and the opinions of the students, the following suggestions are given in order to guide other studies.

- The study was conducted only for limited acquisitions on algebraic expressions in the 7th grade mathematics course. Augmented reality in mathematics course can be used.
- The same study can be used for its effect on variables such as attention and motivation. can be conducted.
- Academic achievement of students by teaching with augmented reality application this study, which shows that learning has a positive effect on a more detailed research by including examinations to determine the permanence executable.
- In terms of AR awareness and usage, prospective computer teacher students and prospective students in different branches can be compared.
- In order to help students when they buy a computer, an AR technology can be developed that shows the working principle when the relevant hardware is selected, informs whether the parts are compatible with each other or shows a solution in case of a technical malfunction.
- In line with the demands of the students after the application, science research by teaching the course with mobile augmented reality application in the course executable.
- Within the scope of the FATIH project, it is thought that it will be useful to provide the necessary technological materials to be able to teach lessons with such activities in the classroom.
- Many studies such as applications on the effect of using augmented reality in distance education courses on informatics, science, social sciences or mathematics courses can be conducted.
- Various studies can be conducted for teachers to develop course materials using AR applications.
- Studies examining the effect of AR-supported materials for students who need special education or have learning difficulties can be conducted.

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