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Research Article

Hope Has Augmented Reality Applications in Science Education Improved Academic Achievement? An Experimental Study

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Abstract

This research was conducted using the random pretest-posttest control group pattern of real experimental design, which is a subset of experimental research designs in the field of quantitative research. The study group consisted of students aged thirteen and fourteen in the eighth grades of private secondary schools affiliated with the Ministry of National Education in Turkey. Twenty students were selected for the experimental group, and twenty students were selected for the control group in an unbiased manner. However, in order to form homogeneous groups, the past academic records of the students of both experimental and control groups were examined before the students were randomly selected. Then, the random selection phase was started. An achievement test was developed for both the control and experimental groups to be used in the research. Additionally, augmented reality flashcards developed by FenAR related to solid, gas, and liquid pressures were used in the experimental group. The collected data were analyzed using the SPSS 25 package program. At the beginning of the study, it was determined that students' academic achievements were similar. Significant achievement was obtained in the experimental group, where augmented reality was used, compared to the class taught with a constructivist approach. Augmented reality, used as an educational tool, provided students with the opportunity to make abstract concepts more concrete and visually experience them. It can be concluded that especially complex science topics, when taught with augmented reality, become more understandable through 3D modeling and interactive simulations.

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Introduction

Science education is a type of education that involves exploring intriguing and stimulating elements in the environment (Kırbaçlar, 2018) and aims to impart essential skills necessary for individuals to sustain their lives (Balbağ et al., 2016). Science plays a significant role in every aspect of our lives (Çepni, 2016) because it enables people to understand phenomena (Kılıç & Moralar, 2015), use scientific methods and state-of-the-art technology

(Özdemir & Sarıkaya, 2012), establish relationships (Kırıkkaya & Şentürk, 2018), analyze problems (Ayvacı, 2021), and develop critical skills essential for education and daily life, such as creative and reflective thinking abilities (Gün & Atasoy, 2017). It even involves observing natural events within a specific order and system (Sadi & Harman, 2022) and making inferences about unobservable situations based on these observations (Çepni, 2016). Science is also considered as scientific knowledge accumulation that helps individuals better understand their socio-cultural environments (Akınoğlu & Tandoğan, 2007). Furthermore, this discipline is highly interactive with advanced technology (Aydoğdu & Kesercioğlu, 2005) and establishes significant connections among various scientific fields (Can et al., 2016).

Over the last few years, one of the prominent research trends in educational technologies, including science education, is the use of augmented reality applications (Aktamış et al., 2013). The impact of these applications on the learning process is increasingly gaining attention (Lee, 2020). Studies show that augmented reality applications have a greater impact on learning achievement compared to traditional face-to-face learning (Yoon et al., 2017). However, the role of augmented reality applications in education is not limited to achievement alone (Turan & Atila, 2021). It has been reported that these applications increase students' motivation (Önal & Önal, 2021), and satisfaction (Gün & Atasoy, 2017). The effects of augmented reality applications in education go beyond student performance (Huang et al., 2016). These applications provide students with a personalized learning environment (Ibanez et al., 2016), allowing them to learn information at their own pace (Kırıkkaya & Başgül, 2019). This enables students to learn more effectively (Aktepe & Aktepe, 2009) while enhancing their imagination (Akçayır & Akçayır, 2017) and creativity (Chin & Wang, 2021).

Research Problem

Changes in the fields of science, industry, and technology have influenced the needs of individuals and society (Pendit et al., 2015), reflecting on educational programs and teaching-learning approaches (Karagözlü, 2021). In Turkey, science education has been revised at various periods to adapt to these changing needs (Balbağ et al., 2016). In 2005, a constructivist approach was adopted, and the "Science and Technology Course Curriculum" was implemented (Aydoğdu & Kesercioğlu, 2005). Some parts of this program were updated in 2008 (Çepni, 2016). Later, starting from the academic year 2013-2014, it was implemented in 5th grades (Sadi & Harman, 2022). Subsequently, it was expanded to middle school levels, emphasizing research-based and inquiry-oriented approaches (Balbağ et al., 2016). With the latest "Science Education Course Curriculum" published in 2018, research and inquiry-based learning were encouraged (Ayvacı, 2021). However, looking at international exams, Turkey's scores in the field of science education are below the world average (Organization for Economic Co-Operation and Development [OECD], 2016). Particularly, according to the results of the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), Turkey's performance in science education has remained below the desired level (Gürlen et al., 2019). However, as a positive note, recent TIMSS and PISA exams show an improvement in Turkey's performance, albeit partially (Yahsi & Kirkic, 2020). Particularly, according to the 2019 TIMSS results, Turkey rose to the 15th place in the field of science education (OECD, 2019). This can be considered a sign of progress in science education in Turkey (Özerbaş & Safi, 2022). However, there is still work to be done in science education. To improve success in science education, adjustments are expected not only in the curriculum (Çepni, 2016) but also in socioeconomic factors (Gürlen et al., 2019), teacher qualifications (Özerbaş & Safi, 2022), and the format of exams (Balbağ et al., 2016). Furthermore, learning methods and instructional technologies should be effectively utilized to enable more students to develop advanced skills such as problem-solving, hypothesis formulation, analysis, and the use of scientific processes (Çoban et al., 2016). Instructional technology involves adapting technology to the teaching process, considering specific or existing curriculum (Arıcı et al., 2019). Through instructional technology, various technologies can be used by determining the achievements based on the targeted field (Gnidovec et al., 2020). Instructional technologies assist in systematically planning the process by designing, developing, implementing, and evaluating instructional materials suitable for the instruction, aiming for effectiveness within the set goals (Carmigniani et al., 2011). One of the technologies starting to be used in education is augmented reality. Augmented reality is an environment supported by both real and virtual objects (Furht, 2011). Nowadays, augmented reality applications can also be used with mobile devices and tablets (Bernarduzzi et al., 2021). Thus, students have the opportunity to interact without disconnecting from the real world, making them more willing to learn (Craig, 2013). The significant contributions of augmented reality in education include the safe simulation of dangerous experiments (Makransky et al., 2019), resolving conceptual misconceptions (Rabbi et al., 2015), and increasing the durability of learning (Wei et al., 2015). Additionally, this technology increases interest in the class (Hassapopoulou, 2018), encourages student participation (Ke & Hsu, 2015), and supports collaborative learning (Cai et al., 2017), For all these reasons, the importance of augmented reality applications in education is increasingly emphasized (Singhal et al., 2012). When the relevant literature was scanned, it was found that dozens of studies on augmented reality had been conducted. Alkhamisi et al., (2013) “the rise of augmented reality“, Arvanitis et al., (2011) ”A prototype mobile augmented reality system for science education“, Bower et al., (2014) “augmented reality in education” Crawford, (2007) "learning to teach science as an inquiry in difficult and somersaulting practice", Hwang et al., (2016) ”an educational game based on augmented reality“. However, most of these studies aim to provide theoretical knowledge about augmented reality. The number of studies conducted in real classroom environments and real learning settings concerning augmented reality in science education is quite limited. Therefore, it can be considered an undeniable fact that studies focusing on how to increase success in science education should be emphasized. Augmented reality applications, can embody abstract concepts and make learning more meaningful by presenting course materials to students with hand-held and interactive three-dimensional models. Providing a visual experience to students, it can attract the attention of students and make the learning process more interesting. It can also increase the interaction and participation of students. On the other hand, it can offer students the opportunity to learn at their own pace and according to their needs. It can even turn theoretical knowledge into practical application by providing students with hands-on learning experiences. For these reasons, it can be assumed that the results of such research will guide teachers, decision-makers, program development specialists, and those responsible for preparing lesson tools and materials. For this reason, such a study is planned.

The Aim and Research Questions of the Study

This study aims to determine the impact of augmented reality applications on academic achievement in science education. In line with this objective, the following hypotheses were investigated:

H_1= The pre-test scores of students in the pressure unit taught with augmented reality are equal to the population means of their academic achievement ($\mu 1=\mu 2$).

H_2= The post-test scores of students in the pressure unit taught with augmented reality differ from the population means of their academic achievement ($\mu 1\neq\mu 2$).

H_3= In the pressure unit taught with augmented reality, students' academic achievement scores vary based on the interaction between experimental-control groups and pre-test-post-test (μ1≠μ2).

Method

Study's Design and Philosophy

This research was conducted using the random pretest-posttest control group pattern of real experimental design, which is a subset of experimental research designs in the field of quantitative research. The main feature of real experimental patterns is that the subjects to be selected to the experimental and control groups are randomly assigned, and the changes that will occur in the dependent variable by interfering with the subjects in the experimental group allow comparison in terms of experimental and control groups. The fundamental characteristic of this design involves the random selection of subjects for both the experimental and control groups (Cohen et al., 2018), allowing for the comparison of changes in the dependent variable resulting from interventions applied to the experimental group (Creswell & Guetterman, 2019) in relation to the control group (Field, 2018). The research was conducted within the framework of realism philosophy and radical structural paradigm. The radical structural paradigm is the paradigm that facilitates the understanding of models and methods in science (Gunbayi & Sorm, 2020). The research design is presented in Table 1.

Table 1. Pretest-posttest control group model of the study

Group	N	Choice	Pretest	Process	Posttest
Experimental Group	20	Random	Application of the Achievement Test to Students Before the Start of Teaching	Subjecting Students to Teaching	The Application of the Achievement Test to the Students After the Completion of the Teaching
Control Group	20	Random			

In the pretest-posttest control group design, there are two groups: the experimental group, formed through unbiased assignment, and the control group. Both groups undergo pretest and posttest measurements (Denscombe, 2020). While augmented reality-related procedures are applied to the experimental group, constructivist approach-related procedures are applied to the control group. In this model, both the experimental and control groups are subjected to a pretest before the procedures begin. After the procedures are completed, both groups undergo a posttest. Subsequently, pretest and posttest scores are compared across the groups.

Research Group

The study group of this research consists of students aged thirteen to fourteen, studying in the eighth grade of official secondary schools affiliated with the Ministry of National Education in Turkey. From these students, 20 students were selected for the experimental group and 20 students for the control group in an unbiased manner. However, in order to form homogeneous groups, the past academic records of the students of both experimental and control groups were examined before the students were randomly selected (Johnson & Christensen, 2020). Then, the random selection phase was started. The teacher of the control group is a teacher with twenty-two years of educational experience. The teacher of the experimental group is an expert teacher with fourteen years of educational experience.

Data Collection Tools

Achievement Test

For the research, an achievement test was developed for both the control and experimental groups. The achievement test items were selected from the “Pressure' unit in the 8th-grade science curriculum, which states that students “explore variables affecting solid pressure, predict variables affecting liquid pressure and test their predictions, and provide examples of the pressure properties of solids, liquids, and gases in everyday life and technological applications.” The number of achievements in the relevant curriculum is indicated as three, and the lesson time is approximately ten hours. The teaching process in the control group related to these achievements lasted about 4-6 hours, while the teaching process in the experimental group lasted about 3-5 hours. Five expert science teachers were involved in ensuring the content validity of the achievement test. The teachers prepared a total of twenty-five multiple-choice questions within the scope of "LGS and TIMSS" questions, including acquisition and new generation questions. As a result of the Lawshe technique to check whether the content validity was achieved, the "Content Validity Index" was calculated as .848. In other words, four questions that were decided to be inappropriate among the prepared questions were removed from the research at the Lawshe technique stage. The remaining twenty-one questions were grouped under the titles of solid, liquid and gas pressure. Item difficulty and item discrimination indices were calculated for the items. The results of the analysis are given in Table 2.

Table 2. Achievement test item analysis results

Items	Pjx	Rjx	Items	Pjx	Rjx	Items	Pjx	Rjx
1	,851	,121	8	,421	,133	15	,652	,092
2	,532	,570	9	,500	,491	16	,481	,310
3	,501	,454	10	,321	,070	17	,484	,531
4	,582	,512	11	,213	,101	18	,636	,472
5	,531	,590	12	,454	,423	19	,631	,573
6	,772	,172	13	,482	,407	20	,501	,434
7	,531	,570	14	,487	,431	21	,481	,538

Notes: *pjx: Item Difficulty Index, rjx: Item Distinctiveness Indexs. Achievement Test Overall Item Difficulty Index: .520 Achievement Test Overall Item Discrimination Index: .487, Item 1 and item 6 in solid pressure, item 8, item 10 and item 11 in liquid pressure, and item 15 in gas pressure were removed from the achievement test due to low item difficulty or item discrimination.*

When the results of the achievement test item analysis are analyzed in Table 2, the first question on solid pressure, questions eight, ten and eleven on liquid pressure, and the fifteenth question on gas pressure were removed from the achievement test. Questions of item difficulty ".50>" and the item distinctiveness index ".40>" were selected from specific questions. Two expert science teachers were asked to help with the content validity of the remaining fifteen questions and Kappa analysis was performed. The evaluations of the two experts were subjected to Kappa analysis, resulting in an inter-coder reliability coefficient [κ=.863 t=6.153 p=.000], indicating a significantly high inter-coder reliability level (Landis & Koach, 1977). Although the item difficulty and item distinctiveness index of the questions were selected from certain questions, Cronbach's alpha reliability calculations were performed for tetrachoric factor analysis and internal consistency analysis to ensure the structural validity of the questions. The KMO value for tetrachoric factor analysis was found to be .856, indicating the suitability of the test questions for tetrachoric factor analysis (Johnson & Christensen, 2020). The achievement test questions were grouped under three factors: "Solid Pressure λ=17.147, Liquid Pressure λ=16.203, Gas Pressure λ=21.845." The explained total variance ratio of these three factors was 55.195%. Upon examining the factor load values for the achievement test, it was found that two questions related to solid pressure, three questions related to liquid pressure, and one question related to gas pressure had factor load values below .300. The other factor load values were .428 and above (Tabachnick & Fidel, 2013). Confirmatory factor analysis model fit results and reference values are given in Table 3.

Table 3. Model fit results and reference values

Model Fit Criterion	Good Fit	Acceptable Compliance	Model Result
X^2 Fit Test	,05 < p ≤ 1	,01 < p ≤ ,05	,079
CMIN / SD	X^2 /sd ≤ 3	X^2 /sd ≤ 5	3,128
Comparative Fit Indices			
CFI	,97 ≤ CFI	,95 ≤ CFI	,983
RMSEA	RMSEA ≤ 0,05	RMSEA ≤ 0,08	,002
Absolute Concordance Indices			
GFI	,90 ≤ GFI	,85 ≤ GFI	,991
Residual-based Cohesion Indices			
RMR	0 < RMR ≤ ,05	0 < RMR ≤ ,08	,002

Source: *Keth, 2019; Kline, 2016*

When the model fit values of the study were calculated, the CMIN/DF value was 3.128, the p-value was .079, the GFI value was .991, the CFI value was .983, and the RMSEA value was .002. The reliability of Cronbach's Alpha value was .925. These values indicated that the developed achievement test was valid and reliable (Collier, 2020). At the first stage of the research, the success test was determined as twenty-one questions, as a result of the validity analysis, the “Pressure of Solids” was applied as five questions, the “Pressure of Liquids” as four questions, and the “Pressure of Gases” as six questions.

Augmented Reality Flashcards and Applications

Applications Made in the Control Group

After the eighth-grade students who were selected impartially in the experimental group were determined, daily plans were created by the lesson teacher. The methods and techniques to be applied have been written in the section narration, question and answer, and role-playing. The section on tools and equipment to be used, eighth-grade science textbooks, YouTube pressure videos, presentations, etc. It is written. Activities related to solids, liquids, and gases have been carried out. Measurement and evaluation activities were carried out at each stage of the subject presentations using the question-and-answer method.

Applications Made in the Experimental Group

The eighth-grade students who were selected impartially in the experimental group were asked to bring tablets or mobile phones for the installation of the augmented reality application.

Figure 1. Augmented reality flashcards and applications

Following the completion of this stage, the students in the experimental group were subjected to a pre-test exam together with the students in the control group to measure the initial levels. The teacher who will enter the classes after the exam stage has prepared daily plans. Group study is written in the method and technical part of the lesson plans, and augmented reality is written in the tools and equipment part. It is stated that mathematical links will not be entered in the explanations section, Pascal will be given as the unit of pressure. Then, solid, liquid, and gas experiments were started with FenAR augmented reality applications. The teacher of the lesson used the augmented reality application together with the students at every stage of the lesson. Measurements and evaluations were made at every stage of the application.

Analysis of Data

SPSS 25, AMOS 23 and JAMOVI 2.4.2 software package was utilized for the data analysis in this study. The kurtosis and skewness reference value for the achievement test data was set at ±1.96 (Wagner, 2015). The normality analysis results of the achievement test are given in Table 4.

Tablo 4. Achievement test normality distribution analysis results

Group	Skewness	Kurtosis
Control Group	,017	-,493
Experimental Group	,027	,004

Note: *The standard error of the skewness coefficient of the experimental and control groups was .374 and the standard error of the kurtosis coefficient was .733.*

The kurtosis and skewness values of the achievement test data fell within these limits, indicating a normal distribution of the data (Denscombe, 2020). In the study, paired samples t-tests and independent samples t-tests were performed for pretest-posttest scores of the achievement test (Stockemer, 2019), and two-way ANOVA was conducted to analyze the differences in pretest-posttest and control-experimental group achievement test scores (George & Mallery, 2019). Independent samples t-test was calculated to compare the pretest and posttest scores obtained from two independent groups (Field, 2018). A paired samples t-test is used to determine differences between two different conditions or times on the same participants or items (Wagner, 2015), while two-way ANOVA is employed for situations involving two categorical independent variables and one continuous dependent variable (Denis, 2019). Cohen's d effect size was also calculated in the study. The reference intervals were based on ".05 small, .15 medium and .25 large" effect size. *Internal validity* indicates that the change in the independent variable in the experiment is caused by the independent variable. One of the biggest factors that could threaten the internal validity of this study was selection error. In order not to fall into the selection error, the students' past academic records were examined before they were selected and the formation of a homogeneous group was ensured. Then, the students were randomly determined by the random pretest-posttest control group pattern, which is the sub-pattern of the real experimental pattern. External validity is the ability of the experimental result to be generalized to events and contexts other than the subjects used in the experiment. To the extent that the subjects used in the experiment represent the universe in which the results of the experiment will be generalized, the external validity of the experiment will be ensured at that rate. Throughout the research, strict adherence to internal validity (Finch et al., 2016), indicating that the observed changes in the dependent variable are indeed due to the independent variable, and external validity (Johnson & Christensen, 2020), indicating that the results can be generalized to contexts beyond the participants used in the study, was maintained.

Findings

The analyses of the academic achievement pretest-posttest scores of the students of the pressure unit processed with augmented reality are given in Table 5.

Table 5. Independent samples t-test analysis results

Test	Group	N	$\bar{X}$	SD	t	p	Cohen's d
Pre-test	Control Group	20	59,33	11,42	,572	,571	,181
	Experimental Group	20	57,33	10,68			
Post-test	Control Group	20	59,99	11,64	4,023	,001***	1,27
	Experimental Group	20	74,33	10,87			

Notes: **p<.05; **p<.01; ***p<.001 Pretest H_a μ Control Group = μ Experimental Group, Pretest Levene's $F_{(1-38)}$=.178 p=.676, Posttest H_a μ Control Group ≠ μ Experimental Group, Posttest Levene's $F_{(1-38)}$=.117 p=.734*

Upon examining the independent samples t-test results in Table 5, it was found that the pretest scores for the control group were 59.33±11.42, and for the experimental group, they were 57.33±10.68. According to the independent samples t-test based on pretest results, there was no significant difference between the scores of the control group and the experimental group [t=0.572, p=0.571]. This finding indicates that the pretest scores for both the control and experimental groups were homogeneous. In light of this result, the hypothesis *"H_1= There is no significant difference between the pretest scores of the students in the pressure unit taught with augmented reality (µ1=µ2)"* is supported. The posttest scores for the control group were found to be 59.99±11.64, and for the experimental group, they were 74.33±10.87. According to the independent samples t-test based on posttest results, there was a significant difference between the scores of the control group and the experimental group [t=4.023, p=.001]. This finding indicates that the posttest scores for the control and experimental groups were heterogeneous. In light of this result, the hypothesis *"H_2= There is a significant difference between the posttest scores of the students in the pressure unit taught with augmented reality (µ1≠µ2)"* is supported. Cohen's d value allows expressing the average difference between the two groups in terms of standard deviation units. This measurement is used to assess the magnitude of the difference between groups (Cohen et al., 2018). In this analysis, it can be stated that the effect size in the post-test is higher in the experimental group. The paired samples t-test analysis results for the comparison of achievement test pretest and posttest scores are given in Table 6.

Table 6. Associated samples t-test analysis results

Test	N	$\bar{X}$	SD	t	p	Cohen's d
Pre-test	40	58,33	10,96	5,653	,001***	,726
Post-test	40	67,17	13,28			

Notes: **p<.05; **p<.01; ***p<.001*

When the paired samples t-test analysis results for the comparison of achievement test pretest and posttest scores are examined in Table 6, the arithmetic mean of the pretest and posttest scores of the experimental and control groups was 58.33±10.96 and the arithmetic mean of the posttest scores was 67.17±13.28. The t-test for the comparison of the averages was significant in favor of the experimental group [t=5.653, p=.001]. The difference between the posttest and pretest scores of both the experimental and control groups was calculated as 8.833. Cohen's d effect size value was found to be .726. This value showed that the effect size between pretest and posttest scores was high. In the study, the achievement test was analyzed under three factors based on the grouping of pressure of solids, liquids and gases. The results of the independent samples t-test analysis of the comparison of these factors between the experimental and control groups are given in Table 7.

Table 7. Independent samples t-test analysis results for the comparison of the achievement test on the pressure of solids, liquids and gases with the experimental and control groups

Test	Group	N	$\bar{X}$	SD	t	p	Cohen's d
Solid Pressure	Control Group	40	20,33	6,40	2,244	,028*	,501
	Experimental Group	40	23,50	6,22			
Liquid Pressure	Control Group	40	18,50	5,34	3,148	,002***	,704
	Experimental Group	40	22,00	4,58			
Gas Pressure	Control Group	40	20,50	5,92	,111	,912	,024
	Experimental Group	40	20,33	7,39			

Notes: **p<.05; **p<.01; ***p<.001 Solid Pressure H_a µ Control Group ≠ µ Experimental Group, Solid Pressure Levene's $F_{(1-78)}$=.438 p=.510, Liquid Pressure H_a µ Control Group ≠ µ Experimental Group, Liquid Pressure Levene's $F_{(1-78)}$=.779 p=.380, Gas Pressure H_a µ Control Group ≠ µ Experimental Group, Gas Pressure Levene's $F_{(1-78)}$=1.183 p=.280,*

When the results of the independent samples t test analysis are analyzed in Table 7; the arithmetic mean and standard deviation values of the solid pressure achievement test were 20,33±6,40 in the control group and 23,50±6,22 in the experimental group; the arithmetic mean and standard deviation values of the gas pressure achievement test were 18,50±5,34 in the control group and 22,00±4,58 in the experimental group; the arithmetic mean and standard deviation values of the gas pressure achievement test were 20,50±5,92 in the control group and 20,33±7,39 in the experimental group. The t-test values for the significant difference between the averages were calculated for solid pressure [t=2,244, p=.028], liquid pressure [t=3,148, p=.002] and gas pressure [t=.111, p=.912]. The significant difference shows an increase in favor of the experimental group in solid pressure and liquid pressure. However, in gas pressure, the achievement test scores of both the experimental group and the control group were close to each other. Cohen's d effect size values were high in solid and liquid pressure. The analyses related to the interaction between the experimental-control group and pretest-posttest for students' academic achievement scores in the pressure unit taught with augmented reality are presented in Table 8.

Table 8. Results of two-way analysis of variance

Variables	Sum of Squares	df	Mean Square	F	p	ή²
Group	761	1	761	6,100	,016*	,058
Test	1561	1	1561	12,520	,001***	,119
Group * Test	1334	1	1334	10,700	,002***	,102
Residuals	9473	76	125			

Notes: **p<.05; **p<.01; ***p<.001 Levene's* $F_{(3\text{-}76)}$*=.162 p=.922*

Upon examining the results of the two-way analysis of variance in Table 8, it was found that both the experimental and control groups (group) significantly influenced the achievement test [$F_{(1,76)}$=6.100, p=.016]. The pretest and posttest group (test) significantly influenced the achievement test [$F_{(1,76)}$=12.520, p=.016]. Furthermore, both the group and test variables together significantly influenced the achievement test [$F_{(1,76)}$=10.700, p=.002]. Since variance homogeneity was ensured in the model, the Tukey test was used for multiple comparisons. According to the results of the Tukey test regarding significant differences, a significant increase was observed in favor of the experimental group students. In light of this result, the hypothesis *"H_3= In the pressure unit taught with augmented reality, students' academic achievement scores vary based on the interaction between experimental-control groups and pre-test-post-test (μ1≠μ2)"* is supported. Eta squared (η²) is a statistical measure obtained from the analysis of variance (ANOVA) and indicates what percentage of the variance in the dependent variable (outcome measurement) is explained by the independent variable (differences between groups) (Creswell & Guetterman, 2019). According to eta squared values, the group*test interaction has a medium-sized effect. A medium-sized effect indicates that the interaction between the group and test factors is significant and contributes to explaining the achievement test results. This information can assist educators and researchers in examining this interaction in more detail and better understanding student performance. The analysis findings demonstrated a significant effect of both the experimental and control groups on the achievement test scores. This suggests that the intervention (experimental group) positively impacted achievement. The result that the experimental group students performed better than the control group emphasizes the effectiveness of the intervention. Additionally, a significant difference was found between the pretest and posttest groups, indicating that achievement test results changed over time, and students' learning processes progressed. This difference between the pretest and posttest results could suggest that students' performance improved or changed as they were exposed to the intervention. It might also imply that the intervention's effect increased over time and could indicate potential long-term effects. Overall, the results show that the experimental group students had higher achievement test scores than the control group, and there was also a significant difference between the pretest and posttest scores. These findings suggest the effectiveness of the intervention, positively influencing students' achievements. Graphs representing the pretest and posttest scores are provided in Figure 2.

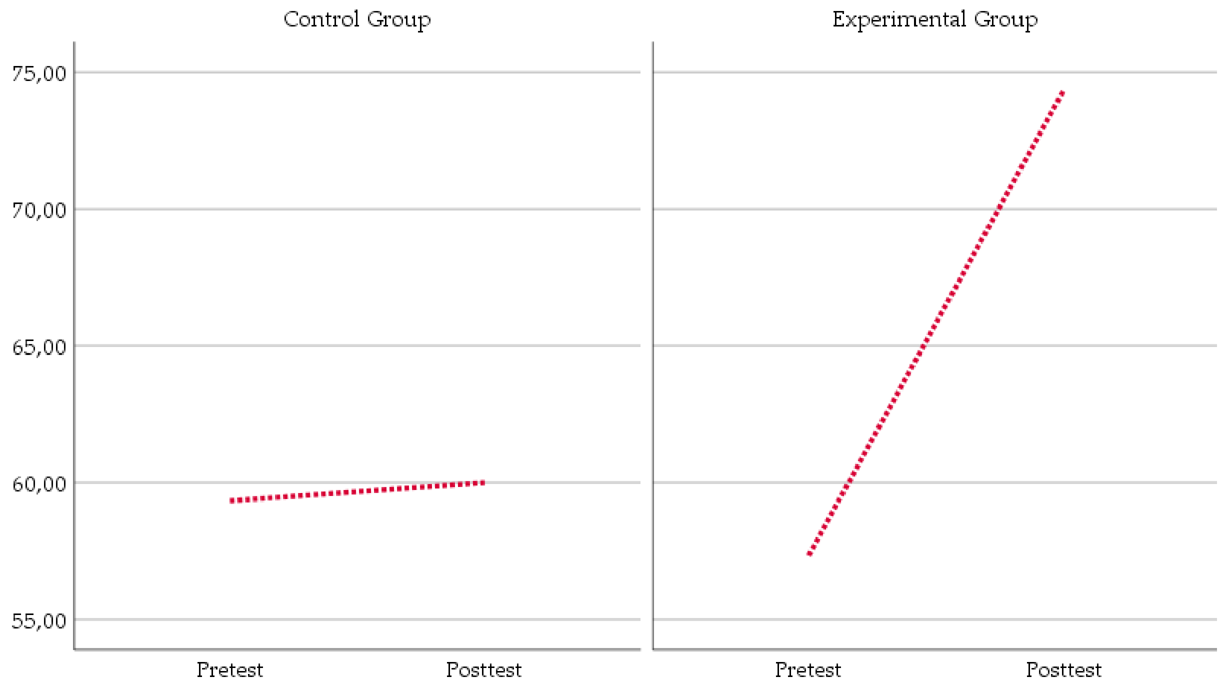

Figure 2. Graph of achievement test, pretest, and posttest scores

Upon examining the graph representing the pretest and posttest scores in Figure 2, a significant increase in achievement test scores was not observed among students in the control group who received instruction through the constructivist approach. However, students in the experimental group, who received instruction using augmented reality, demonstrated a noticeable increase in their achievement test scores.

Discussion, Conclusion and Recommendations

The pretest scores of students in the pressure unit taught with augmented reality are distributed homogeneously. This situation indicates that students' pretest scores are very similar to each other, and there is no significant score difference among different student groups. The participants selected for the study are eighth-grade students in middle school. To ensure that the pre-academic achievement levels of these students are close to each other, their academic records were thoroughly examined, and students with similar achievement levels were included in the study. Upon the analysis of pretest scores, no significant difference was detected in students' scores. In fact, students in the experimental group even had slightly lower achievement scores compared to students in the control group. The lessons with the structured approach were continued with these students, and the pressure unit was taught using augmented reality with the experimental group. This situation completely captivated students' attention, motivation, and desire to learn. Students eagerly installed augmented reality applications on their tablets and smartphones, and observing flashcards in four dimensions further enhanced their interest in the lessons. Since the pressure unit had a limited number of achievements and lessons, the augmented reality applications for students were also brief. However, students in the experimental group constantly expressed their desire for augmented reality applications to continue. After the lessons were completed, the posttest was administered, and it was found that the academic achievement posttest scores of students in the pressure unit taught with augmented reality were distributed heterogeneously. While no significant improvement was observed in the posttests of the control group, a remarkable increase was observed in the posttests of the experimental group. Moreover, students in the experimental group did not exhibit undesirable behaviors; furthermore, they arrived at the classroom minutes before the lessons began. This situation suggests that the use of augmented reality applications in science lessons could make learning more effective and increase students' achievements (Makransky et al., 2019). However, the potential to enhance achievement can vary based on the design of the application, its usage, and how well it meets the needs of the students (Chiang et al., 2014). Augmented reality in science, especially in the context of education and laboratory studies, is an exciting technological development (Küçük et al., 2016). Augmented reality can offer students the opportunity to conduct laboratory experiments in a virtual environment (Radu, 2014). For example, chemistry students can observe chemical reactions or biology students can examine intracellular processes (Lu & Liu, 2015). This can facilitate learning in schools where laboratory access is limited or situations where it is difficult for students to repeat experiments (Squire & Jan, 2007). In biology classes, it can provide opportunities for students to better understand the internal structure or functioning of living organisms (Almasseri & AIHojailan, 2019). For instance, students can view the internal organs or cells of an organism in 3D. Augmented reality can also allow science students to observe and study stars, planets, and other celestial bodies (Sommerauer & Müller, 2014). Using smartphones or tablets, students can recognize celestial objects (Alhalabi, 2016). In physics classes, it can offer various experiments to help students better understand physical principles (Hsiao et al., 2012). For example, virtual experiments can be conducted on electrical circuits or mechanical movements. Augmented reality can help students work more effectively in geographical areas. They can examine layers virtually and have a better understanding of geological formations (Lin et al., 2015). These statements align with the research findings. Augmented reality in science is a powerful technology that can enhance learning and achievement (Gün & Atasoy, 2017). Augmented reality is defined as a technology that enriches the real world with virtual elements (Turan et al., 2018). When used in science education, it can help students understand experimental studies more effectively (Singh et al., 2019), visualize experiments, and learn complex concepts better (Jamali et al., 2015).

In the pressure unit taught with augmented reality, students' academic achievement scores vary based on the interaction of experimental-control groups and pretest-posttest. Based on the experimental results in the pressure unit taught with augmented reality, it was observed that the experimental group outperformed the control group. This result indicates that augmented reality technology enhances the learning experience and deepens students' understanding of the pressure topic (Moro et al., 2017). There could be several possible reasons for the experimental group's superior performance. Firstly, augmented reality can help students understand abstract or complex concepts more visually and interactively (Estapa & Nadolny, 2015). This technology can concretize pressure-related concepts and make learning more engaging by demonstrating how they work in the real world (Laine et al., 2016). Additionally, one reason behind the success of the experimental group might be that the pressure unit taught with augmented reality provided a learning environment that better suited students' learning styles and needs (Thees et al., 2020). This technology enables students to learn at their own pace and have more interactive experiences (Martin-Gonzalez et al., 2016), while also allowing teachers to provide more personalized education (Graham et al., 2013). In conclusion, the experimental group's performance in the pressure unit taught with augmented reality emphasizes the potential of this technology in education. However, it is important to remember that these results require further research and analysis because various factors could affect student achievement. The experimental results in the pressure unit taught with augmented reality indicate that the experimental group outperformed the control group. These results suggest that a constructivist approach is less effective compared to the education approach supported by augmented reality technology. One reason behind the experimental group's higher achievement might be that augmented reality provided students with a more interactive and visual learning experience (Lai et al., 2019). This technology concretized abstract concepts and allowed students to visually experience pressure-related concepts (Arvanitis et al., 2011). The control group, lacking this visual experience, might have lagged in achievement. However, it should be noted that the difference in achievement could be attributed to other factors as well. For instance, variables such as the number of students in the experimental and control groups, the profile of students in each group, and the teacher's level of experience could influence the results. Therefore, further research and analysis may be necessary to fully understand the reasons for the control group's lower achievement. These findings can help educators think about how to use innovative technologies like augmented reality more effectively to enhance learning experiences (Mystakidis et al., 2022), improve student achievement (Yen et al., 2013), and consider how to use innovative technologies like augmented reality more effectively (Yu et al., 2022).

The use of augmented reality in science education has been found to significantly improve students' post-test scores in the experimental group, while there has been no significant improvement in the class taught using the constructivist approach. It can be inferred that augmented reality-based lessons provide experimental group students with a more effective, visual, and engaging learning experience and offer teachers better tools to explain complexity and abstract concepts. This technology aids in a better understanding of science concepts and enables students to explore topics more deeply. The pressure unit taught with augmented reality positively influenced students' academic achievements in comparison to the constructivist approach. A significant difference emerged between the experimental and control groups. However, we can say that for augmented reality to contribute to success, it must be well-designed and used for educational goals.

The use of augmented reality in science education holds great potential in the fields of learning, research, and application. Augmented reality can be employed to visualize complex concepts and processes. It offers students the opportunity to explore molecular structures, cellular functions, or physical phenomena in greater depth. Augmented reality can enhance real-world laboratory experiences for students. They can conduct experiments and observe results using virtual objects. Providing interactive augmented reality applications to students for exploring scientific subjects can encourage self-paced learning. Particularly, when explaining complex molecular structures or physical phenomena, visual understanding can be provided to students through 3D modeling and animations. Additionally, science textbooks can be designed to be compatible with augmented reality.

Ethical Committee Permission Information

Name of the board that carries out ethical assessment: Çukurova University Social and Humanities Scientific Research and Publication Ethics Board

The date and number of the ethical assessment decision: 01.06.2023 -10

Author Contribution Statement

***Savaş VARLIK:** Conceptualization, literature review, data curation, methodology, implementation, data analysis, original draft, language editing, organization, and writing.*

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