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Original Article

The Effects of Different Teaching Applications on Academic Success and Retention in the Fraction Subject

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Abstract

This study examined the effects of implementing achievement goals in teaching fractions to 5th-grade secondary school students through different instructional approaches—traditional, game-based, and technology-enhanced—on academic achievement, retention, and students' perceptions of these methods. A sequential explanatory mixed-methods design was employed. The quantitative phase used a quasi-experimental pre-test–post-test control group design, while the qualitative phase was conducted using a case study approach. The sample consisted of 51 students enrolled in a public secondary school and was divided into three groups: a control group receiving traditional teaching method, experimental group I receiving game-based teaching, and experimental group II receiving technology-enhanced teaching Quantitative results indicated no statistically significant differences among the groups in post-test achievement scores. However, the retention test results showed that game-based instruction was significantly more effective than the traditional teaching method. Qualitative findings showed that students generally evaluated the experimental methods positively. Game-based teaching was emphasized for increasing interest and enjoyment, whereas technology-enhanced teaching was reported to enhance participation and motivation. Despite these positive outcomes, students also identified certain limitations, including the fact that games may not appeal to all learners and that technology can sometimes lead to distractions.

Keywords: Fractions, game-based teaching, technology-enhanced teaching, traditional teaching method, student opinions

Introduction

The learning profiles of today's students differ from those of previous generations, resulting in diverse learning needs and requirements. Therefore, it is essential to adopt new teaching methods and techniques tailored to these changing student needs (Kiryakova et al., 2014). The needs of students of all age groups vary. Previous research has reported positive cognitive and affective outcomes associated with game-based learning in mathematics education (Hui & Mahmud, 2023; Vankúš, 2021). Coşkun (2006) states that teaching with games is a method that reinforces and repeats learned information in a more comfortable environment. In addition, games encourage the participation of even the most passive students in classroom activities and contribute to creating a comfortable atmosphere in the classroom environment (Hui & Mahmud, 2023; Vankúš, 2021). In mathematics education, games have also been discussed as instructional contexts that can establish meaningful connections between mathematical ideas and students' learning experiences (Uğurel & Moralı, 2008). Therefore, it can contribute positively

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to both students' academic success and social communication skills (Barata et al., 2013; Hanus & Fox, 2015; Lee & Hammer, 2011).

While the game-based teaching method encourages students' active participation in the learning process, the increasing role of technology in education also offers new possibilities for learning environments (Kirkwood & Price, 2013). In fact, another approach that attracts attention, as well as the contributions of game-based teaching to the educational process, is technology-enhanced teaching(Johnson et al., 2014). It is well established that technology-enriched, interactive, and visual learning environments make significant contributions to mathematics education (Karadag & McDougall, 2009). It is also stated that technology-enhanced teaching environments transform not only teaching and learning strategies, but also the structure of curricula and the way mathematical content is presented (Pierce & Stacey, 2010; Drijvers, 2015). In addition, the effective use of technology in lessons enables students to deepen their conceptual and operational knowledge, contributing to teachers managing the teaching process more efficiently (Hohenwarter et al., 2009; Thomas & Holton, 2003).

Traditional teaching methods can provide a systematic and structured learning environment, helping students learn in a disciplined manner (Demir & Bilgin, 2021). Technology-enhanced teaching environments, on the other hand, can facilitate the understanding of concepts by providing visual and interactive materials, thereby supporting long-term recall of information, which is its retention(Senemoğlu, 2007). However, teaching through play can support students' active participation in the lesson, thereby increasing their motivation and making the learning process more effective (Lee & Hammer, 2011). In this context, the preferred teaching method in the mathematics teaching process can significantly impact students' success and motivation (Hiebert & Grouws, 2007). Integrating different methods beyond traditional learning approaches enables students to develop their conceptual understanding and enhance their ability to tackle new problems, rather than relying solely on rote learning (Boaler, 2002).

From a cognitive perspective, game-based and technology-enhanced teaching may influence learning and retention through different but complementary mechanisms. Game-based learning can promote cognitive, behavioral, and affective engagement by requiring learners to actively interact with learning tasks, make decisions, apply previously acquired knowledge, and receive feedback during the learning process (Plass et al., 2015). Such active engagement may encourage learners to process instructional content more meaningfully rather than merely receiving information passively. Technology-enhanced teaching can also support cognitive processing when verbal, visual, and interactive representations are meaningfully integrated. According to the Cognitive Theory of Multimedia Learning, meaningful learning occurs when learners select relevant verbal and visual information, organize it into coherent mental representations, and integrate these representations with prior knowledge stored in long-term memory (Mayer, 2024). However, both approaches need to be appropriately designed because working memory has a limited processing capacity. Cognitive Load Theory suggests that instructional environments that direct learners' cognitive resources toward relevant information can facilitate learning, whereas unnecessary stimuli or excessive information may impose extraneous cognitive load and interfere with learning (Sweller et al., 2019). Thus, game-based and technology-enhanced teaching may support longer-term retention by facilitating active and meaningful cognitive processing. However, their effectiveness may decrease when game elements, visual features, or technological stimuli distract attention from the learning content.

The concept of a fraction is one of the abstract ideas that students encounter for the first time, which is crucial to their conceptual understanding. In fact, as a generalized form of the concept of number, it forms the basis for students to make sense of rational numbers, ratio-proportion relations, and percentages (Behr et al., 1983). Making sense of the concept of fractions at the primary school level contributes to students' ability to perform operations based on this concept in a meaningful way and to develop related mathematical skills (NCTM, 2000). When the secondary school mathematics curriculum

is examined, the concept of fractions is important because it establishes strong relationships with concepts such as ratios, proportions, percentages, algebraic expressions, and measurement (Haser & Ubuz, 2003; Lamon, 2007). Therefore, the meaningfulness of learning about the concept of fractions not only enables the development of mathematical competencies but also allows students to use fractions effectively in daily life situations and in different disciplines (Empson & Levi, 2011). In this context, the concept of fractions can be seen as a foundational area for learning advanced mathematics subjects, which improves students' conceptual and operational knowledge levels.

The abstract nature of mathematics can cause students to struggle with understanding mathematical concepts and develop negative attitudes towards the subject. To eliminate these negative attitudes, it is recommended that various methods and techniques be employed in the teaching process (Gürsoy, 2010). In fact, the teaching methods employed in the classroom can have a direct impact on students' learning experiences. One of the reasons for the inability to achieve permanent learning and the emergence of conceptual inaccuracies is the preferred teaching methods (Dinçer, 2019; Sarıer, 2020). This research aims to examine the effect of implementing teaching processes related to class fractions subject achievements using different teaching practices (traditional teaching method, game-based teaching method, and technology-enhanced teaching method) on academic achievement and retention in students, and to determine students' opinions on these different teaching practices. Within the scope of this purpose, the questions of the research are defined as follows:

1. Is there a significant difference between the mathematics achievement post-test scores of the experimental group students who studied with the game-based teaching method and the technology-enhanced teaching method, and the mathematics post-test success scores of the control group students who studied with the traditional teaching method?
2. Is there a significant difference between the mathematics achievement retention test scores of the experimental group students who studied with the game-based teaching method and technology-enhanced teaching method, and the mathematics achievement retention test scores of the control group students who studied with the traditional teaching method?
3. What are the students' opinions on the use of game-based teaching methods in mathematics lessons?
4. What are the students' opinions on the use of technology-enhanced teaching methods in mathematics lessons?

Methodology

Research Model

In this study, a sequential explanatory mixed-methods design was employed, combining qualitative and quantitative approaches. Conducting research that utilizes both quantitative and qualitative data helps us understand problems more effectively than relying on only one approach (Johnson & Onwuegbuzie, 2004). In this study, a sequential explanatory design was employed, as the analysis of qualitative data commenced after the collection and analysis of quantitative data (Creswell, 2021). In this study, the findings obtained from quantitative data are prioritized, and the aim is to support them with the findings from qualitative data analysis.

A quasi-experimental design was used in the quantitative dimension of the research. In the qualitative stage, the process was conducted using a case study design. The three existing class sections were randomly assigned to two experimental groups and one control group. The experimental design of the research is presented in Table 1.

Table 1
Experimental Design of the Research

Group	Pre-test	Method	Post-test	Retention Test
Experiment I	Fractions Achievement Test	Game-Based Teaching Method	Fractions Achievement Test	Fractions Achievement Test
Experiment II	Fractions Achievement Test	Technology-Enhanced Teaching Method	Fractions Achievement Test	Fractions Achievement Test
Control	Fractions Achievement Test	Traditional Teaching Method	Fractions Achievement Test	Fractions Achievement Test

Upon examining Table 1, it is evident that the first experimental group utilized the game-based teaching method, while the second experimental group employed the technology-enhanced teaching method. It is observed that the courses in the control group are conducted in accordance with the teaching methods outlined in the curriculum. Each group was pre-tested, post-tested, and retention tested.

Universe and Sample/Study Group

The quantitative phase of the study consisted of 5th-grade students. The study sample comprised 51 fifth-grade students from a public secondary school where the researcher worked. The school was selected using a non-random, convenience-based sampling approach due to accessibility and practical considerations, including time, cost, and labor (Creswell, 2021). The 51 students were enrolled in three existing class sections, with 17 students in each section. Thus, the selection of the study sample was non-random; however, the existing class sections were assigned to the experimental and control conditions through random assignment. In the qualitative phase, 20 students from the two experimental groups were randomly selected to participate in interviews.

Assignment of experimental and control groups

After the sample had been identified, the three existing fifth-grade class sections were assigned to the experimental and control conditions. The students' previous mathematics report card grades were examined to assess the initial equivalence of the class sections. Following this assessment, the three class sections were randomly assigned to the study conditions. Accordingly, 5-A was assigned to Experimental Group I, 5-C to Experimental Group II, and 5-B to Control Group. Experimental Group I received the game-based teaching method, Experimental Group II received the technology-enhanced teaching method, and Control Group received traditional teaching method based on the curriculum. The data obtained are presented in Table 2.

Table 2
Equivalence of Students' Mathematics Grades

Class Branches	N	$\overline{X}$	SD	F	P
5-A	17	65,24	27,856		
5-B	17	60,24	15,135	,216	,806
5-C	17	63,53	22,796		
Total	51	63,00	22,187		

Table 2 presents the school report card grades for the mathematics course from previous semesters for students studying in different branches. According to Table 2, it can be seen that the students' mathematics report card averages are relatively close to one another. As a result of the SPSS analysis, no significant difference was found between the mathematics grades of the experimental groups and the control groups ($F = 0.216$, $P = 0.806$, $p > 0.05$). The methods applied to the students and their distribution to the classes are given in Table 3.

Table 3
Class Sizes in Research

Groups	Class	Applied Technique	Class Size
Experimental Group-I	5/A	Game-Based Teaching Method	17
Experimental Group-II	5/C	Technology-Enhanced Teaching Method	17
Control Group	5/B	Traditional Teaching Method	17

A 16-question "Mathematics Achievement Test (MAT)" was applied to the students in the experimental and control groups participating in the research. For the validity of the ANOVA analysis, it was checked whether the data were normally distributed. For this purpose, a normality test was applied to each group, and the normality of the distribution was evaluated. It was observed that the distribution was normal. The distribution of mathematics achievement test scores according to pre-test scores is shown in Table 4.

Table 4
ANOVA Results on the Comparison of Students' Mathematics Achievement Pre-Test Levels According to Class Sections

	Groups	N	$\overline{X}$	Ss	F	P
MAT Levels	5-A	17	3,59	1,938	2,384	,103
	5-C	17	3,88	1,933		
	5-B	17	5,00	2,092		
	Total	51	4,16	2,043		

When Table 4 is examined, it is evident that there is no significant difference in students' mathematics achievement pre-test scores according to class sections, as determined by the ANOVA test [$F(2, 48) = 2.384$, $p > .05$]. In other words, when the mean scores are examined according to class sections, no significant difference was observed among the mean scores of students in the 5-A ($M = 3.59$), 5-B ($M = 5.00$), and 5-C ($M = 3.88$) sections.

Data collection tools

In this study, "Mathematics Achievement Test (MAT)" and "Semi-Structured Interview Form " were used as data collection tools.

Mathematics achievement test

While preparing the MAT, the researcher developed four questions for each of the eight learning outcomes related to the "Fractions" and "Operations with Fractions" subjects. In line with the opinions of two mathematics teachers and a mathematics education expert, the number of questions was reduced from 32 to 16, taking into account the time management and motivation of the students. For the pilot application, the fractions mathematics achievement test was applied to sixth-grade students. The results of the analysis, based on the obtained data, are presented in Table 5.

Table 5

First Pilot Application Data Internal Consistency Analysis

Question No	Test Average When Item Deleted	Variance of the Test When Item Deletion	Adjusted Item-Total Correlation	If the item is deleted, the Kuder-Richardson KR-20 coefficient
Q.1	5,2759	8,993	,108	,689
Q.2	5,3448	8,448	,294	,665
Q.3	5,2759	8,421	,306	,663
Q.4	5,2759	8,278	,358	,656
Q.5	5,5172	7,973	,520	,636
Q.6	5,1379	8,409	,346	,658
Q.7	5,5862	8,537	,334	,660
Q.8	5,4828	8,616	,256	,670
Q.9	5,5862	8,180	,484	,642
Q.10	5,4828	8,187	,417	,649
Q.11	5,4483	8,470	,300	,664
Q.12	5,5862	8,180	,484	,642
Q.13	5,6207	8,101	,556	,636
Q.14	5,5517	9,756	-,136	,714
Q.15	5,6552	9,591	-,068	,701
Q.16	5,5862	9,394	-,003	,698

The reliability of a test shows how accurately the measured feature is evaluated and can be expressed as the consistency between the responses to the test items (Blaikie, 2003). The reliability analysis of the test was conducted using a rating system, where correct answers were coded as 1 and incorrect and blank answers were coded as 0. As a result of the reliability analysis of the achievement test, which consisted of 16 questions, the KR-20 value was determined to be 0.681. It was observed that when questions 14 and 15 were modified, the test's reliability increased. These questions were replaced with others that yielded similar outcomes and were applied to sixth-grade students again. The results of the second pilot application are presented in Table 6.

Table 6
Second Pilot Data Internal Consistency Analysis

Question No	Test Average When Item Deleted	Variance of the Test When Item Deletion	Adjusted Item-Total Correlation	If the item is deleted, the Kuder-Richardson KR-20 coefficient
Q.1	9,4412	16,133	,395	,861
Q.2	9,3529	16,114	,453	,858
Q.3	9,2353	17,276	,177	,868
Q.4	9,3529	15,993	,490	,857
Q.5	9,5000	15,288	,605	,851
Q.6	9,2353	16,488	,478	,858
Q.7	9,8529	16,008	,462	,858
Q.8	9,6176	15,395	,555	,854
Q.9	9,3529	15,690	,583	,853
Q.10	9,4706	15,651	,516	,856
Q.11	9,6176	15,637	,491	,857
Q.12	9,5294	15,408	,563	,853
Q.13	9,5882	15,280	,588	,852
Q.14	9,7353	16,261	,342	,864
Q.15	9,4118	15,704	,531	,855
Q.16	9,4706	15,166	,652	,849

Following the second pilot application, the KR-20 value was calculated to be 0.864. Upon examining Table 6, it was observed that the questions were close to this value. This result reveals that the mathematics achievement test is reliable at the desired level and suitable for application. The distribution of questions according to the achievements of the "MAT" is shown in Table 7.

Table 7
MAT Specification Table Covering "Fractions" and "Operations with Fractions"

Learning Outcomes	Questions
1. Shows and sorts unit fractions on the number line.	Q1, Q2
2. Understands that a whole number fraction is the sum of a natural number and a simple fraction and converts the whole number fraction to a compound fraction and a compound fraction to a whole number fraction.	Q3, Q4
3. Compares a natural number with a compound fraction.	Q5, Q6
4. Understands that simplification and expansion will not change the value of the fraction and creates fractions equivalent to a fraction.	Q7, Q8
5. Lists fractions with equal numerators or denominators	Q9, Q10

Learning Outcomes	Questions
6. Calculates the desired simple fraction of a multiplicity and the entire multiplicity given as a simple fraction by using unit fractions.	Q11, Q12
7. Performs and makes sense of the addition and subtraction of two fractions whose denominators are equal or the denominator of one is a multiple of the denominator of the other	Q13, Q14
8. Solves and establishes problems that require addition and subtraction operations with fractions whose denominators are equal or the denominator of one is a multiple of the denominator of the other.	Q15, Q16

When Table 7 is examined, it is evident that 12 questions are asked on the subject of "Fractions" and four questions are asked on the subject of "Operations with Fractions." As a result, it was decided to administer the mathematics achievement test to both the experimental and control groups as a pre-test, post-test, and retention test.

Semi-structured interview form

A semi-structured interview form was used to gather the opinions of students in the experimental groups, where the game-based teaching method and technology-enhanced teaching would be applied. Thus, students' opinions will be sought regarding the application of game-based teaching and technology-enhanced teaching. It aims to gain an understanding of the positive aspects and negative points of the applications for future research. For this purpose, five questions for teaching with games and five questions for technology-enhanced teaching were prepared by examining questions from similar applications from the relevant literature reviews. The semi-structured interview forms were examined by three mathematics and two literature teachers. "Questions can be arranged more simply in a way that students can understand." "The content of a few questions should be arranged in a way that reflects the real experiences of the participants." "Attention should be paid to spelling rules." The final versions of the interview forms were created in line with the feedback.

Data collection process

The research implementation process lasted eight weeks. First, MAT was administered as a pre-test to all students in all three groups. Then, in Experimental Group I, each learning outcome was reinforced through games aligned with the relevant learning objective. In this context, the games “What’s Wrong?”, “Let’s Get to Know the Fractions”, “Bingo Game with Fractions”, “Which Number?”, “We Expand the Saltshakers,” “Grab the Equal, “Sort the Same Colors,” and “Tic-Tac-Toe” were applied, respectively. The games were directly aligned with the targeted learning outcomes related to fractions and operations with fractions. Their implementation emphasized active student participation, group interaction, practice, and reinforcement of previously learned content, and opportunities for corrective feedback. These pedagogical features are consistent with the literature emphasizing that game-based learning can promote active engagement and meaningful interaction with learning content (Lee & Hammer, 2011; Plass et al., 2015). In Experimental Group II, technology-enhanced teaching was supported by activities and instructional content from the Education Information Network (EBA), GeoGebra, and Derslig.com, selected in relation to the targeted fraction learning outcomes. These digital resources were used to support the presentation and practice of fraction concepts through visual and interactive learning opportunities. This pedagogical use of technology is consistent with the literature emphasizing that visual and interactive digital environments can support students’ conceptual understanding and engagement with mathematical content (Karadağ & McDougall, 2009; Hohenwarter et al., 2009).

Data analysis

The SPSS 23.0 program was used for analyzing the data obtained from the research. Normality tests were applied to select the appropriate test for the first and second sub-problems. The results of the Kolmogorov-Smirnov and Shapiro-Wilk tests are shown in Table 8.

Table 8

Kolmogorov-Smirnov and Shapiro-Wilk Test Results of Students' Mathematics Achievement Post-Test and Retention Scores

	Kolmogorov-Smirnov			Shapiro-Wilk		
	Statistics	Df	p	Statistics	Df	p
Final Test	.182	51	< .001	.938	51	.010
Retention	.179	51	< .001	.926	51	.004

As a normality test, the results of the Shapiro-Wilk test were interpreted because the data set contained fewer than 100 observations (Field, 2018). Both the post-test (p <.010), as well as for retention (p = .004), the Shapiro-Wilk test result found p significance values are meaningful (p <.05). Accordingly, it was deemed appropriate that the tests to be performed for the first and second sub-problems should be the non-parametric Kruskal-Wallis test. If there is a significant difference in the Kruskal-Wallis test result, it is deemed appropriate to make pairwise comparisons between the groups using the Mann-Whitney U Test.

The content analysis method was employed in analyzing the data obtained from semi-structured interview forms. Cohen et al. (2000) defined content analysis as a method that involves summarizing and explaining the basic contents of written materials and the messages they convey. In content analysis, the process can be examined in four basic stages: (1) coding the data, (2) identifying the themes, (3) organizing the codes and themes, and (4) interpreting the findings. First, the forms on which the students' opinions were recorded were coded. While coding, "S1, S2, ..." coding was preferred. After coding, the themes within which the data would be collected were determined by two mathematics education experts in line with the established structure. Reliability calculations were made based on the items with "consensus" and "disagreements" determined by researchers working independently of each other. The following formula was used for reliability calculation: Reliability = (Consensus) / (Consensus + Disagreement). Miles and Huberman (1994) consider a study to be reliable if its reliability calculation exceeds 70%. The reliability calculation result obtained in this research was considered reliable, as it was 75%. The qualitative data obtained in the research were quantified using percentiles and frequency calculation techniques. In addition to the qualitative data presented in the table, examples of each student's opinion are provided. In the examples provided, attention was given to providing an equal number of examples of both negative and positive opinions.

Findings

In the first sub-problem of the research, the aim was to examine whether there was a significant difference between the mathematics achievement post-test scores of students in the experimental groups and the control group. In this context, the Kruskal-Wallis Test was used to examine whether there was a significant difference in the mathematics post-test success scores of the participants. The findings regarding the data obtained are shown in Table 9.

Table 9
Kruskal-Wallis Test Results on Mathematics Post-Test Scores by Method of Education

Group	N	Rank Average	Df	χ^2	P
Game-Based	17	32.68			
Technology-Enhanced	17	23.03	2	5.22	.073
Traditional	17	22.29			

When Table 9 is examined, the non-parametric Kruskal-Wallis test was applied instead of the parametric ANOVA test to compare the mathematics post-test scores of students who learn through game-based, technology-enhanced, and traditional methods, as the test scores were not normally distributed. It was found that there was no significant difference between the student groups according to the training method ($\chi2 = 5.22$, $p = .073$). Accordingly, it can be said that there is no difference between student groups with different teaching methods in terms of post-test scores.

In the second sub-problem of the research, the aim was to investigate whether there was a significant difference in the retention test (MAT) scores between the experimental groups and the control group. In this context, the Kruskal-Wallis Test was used to examine whether there was a significant difference in the retention test (MAT) achievement scores of the participants. The findings regarding the data obtained are shown in Table 10.

Table 10
Kruskal-Wallis Test Results on Mathematics Retention Test Scores by Method of Education

Group	N	Rank Average	Df	$\chi2$	p
Game-Based	17	33.29			
Technology-Enhanced	17	23.85	2	6.59	.037
Traditional	17	20.85			

When Table 10 is examined, the non-parametric Kruskal-Wallis test was applied instead of the parametric ANOVA test to compare the retention test scores, as the test scores were not normally distributed. It was found that there was at least one significant difference between student groups according to the training method ($\chi2 = 6.59$, $p = .037$). The effect size of the significant difference is calculated using the formula $\eta^2 = \chi^2 / (N - 1)$, where N is the total sample size. The value of 0.13, which represents the η^2 (eta squared) value, indicates that the teaching method has a small effect on the retention test scores.

When the retention test scores of three different groups were examined, it was found that there was a significant difference between at least two groups. Therefore, the groups were subjected to the Mann-Whitney U test separately to determine which groups had a significant difference.

Game-Based – Technology-Enhanced Comparison

The findings of the Mann-Whitney U Test on the difference between the game-based and technology-enhanced teaching groups are shown in Table 11.

Table 11

Mann-Whitney U Test Results of Mathematics Achievement: Retention Test Scores of Students in Game-Based and Technology-Enhanced Groups

Group	N	Rank Average	Ordinal Sum	U	p
Game-Based	17	20.76	353.00	89.00	.053
Technology-Enhanced	17	14.24	242.00		

Upon examining Table 11, it was found that there was no significant difference in retention test scores, as determined by the Mann-Whitney U Test ($U = 89.00$, $p = .053$).

Game-Based – Traditional Comparison

The results of the Mann-Whitney U Test on the difference in retention test scores between groups of students are shown in Table 12.

Table 12

Mann-Whitney U Test Results of Mathematics Achievement: Retention Test Scores of Students in Game-Based and Control Groups

Group	N	Rank Average	Ordinal Sum	U	p
Game-Based	17	21.53	366.00	76.00	.018
Traditional	17	13.47	229.00		

Upon examining Table 12, a significant difference in the retention test scores of the students was found, as determined by the Mann-Whitney U Test ($U = 76.00$, $p = .018$). Considering the rank averages, the mathematics test success scores of students taught using the game-based method were higher than those of the students in the traditional group. In other words, the significant difference was in favor of the students in the game-based group ($21.53 > 13.47$).

Technology-Enhanced – Traditional Comparison

The results of the Mann-Whitney U Test on the difference in retention test scores between groups of students are shown in Table 13.

Table 13

Mann-Whitney U Test Results of Mathematics Achievement: Retention Test Scores of Students in Technology and Traditional Groups

Group	N	Rank Average	Ordinal Sum	U	p
Technology-Enhanced	17	18.62	316.50	125.50	.506
Traditional	17	16.38	278.50		

Upon examining Table 13, it was found that there was no significant difference between the retention test scores of students, as determined by the Mann-Whitney U Test ($U = 125.50$, $p = .506$).

In the third sub-problem of the research, the opinions of students who learn through game-based learning were examined. The findings regarding the data obtained are shown in Table 14.

Table 14

Opinions of Students in the Game-Based Group

Themes with Game-Based	Categories	Frequency (f)	Percentage (%)
Positive Aspects	Developing a Positive Attitude Towards the Course	ST1, ST3, ST4, ST6, ST8, ST9	% 27,3
	Increasing Interest in the Lesson	ST1, ST6, ST8	% 13,6
	Increasing Academic Success	ST1, ST2, ST7, ST8, ST9	% 22,7
	Providing Learning with Fun	ST3, ST4, ST5, ST6, ST7, ST10	% 27,3
	Engaging Games	ST7, ST10	% 9,1
Negative Aspects	Noise in the Classroom	ST4, ST7, ST8, ST9	% 33,3
	Not Being Able to Reflect on What She/He Knows Because He Is Excited	ST5	% 8,3
	Some Students Don't Want to Game	ST1, ST10, ST5	% 25
	Games Are Not Appealing to Every Student	ST3, ST5	% 16,6
	Disruption in Class Harmony	ST4, ST10	% 16,6

*ST: Student

When Table 14 is examined, it is mentioned that the most positive opinions are to improve the attitude towards the lesson and to learn by having fun (27.3%). In the negative opinions, noise in the classroom was mentioned the most (33.3%). Some of the answers given by the students regarding their positive opinions about teaching through games are presented below:

ST1: "My interest in the lesson is increasing."

ST2: "It affects my success in the course well."

ST6: "It affects it very well; it is better reinforced when you play games about the subjects."

ST8: "When it was fun, it made us love the lesson and positively affected our success by increasing our interest."

ST10: "The games allowed us to have a lot of fun in the classroom environment."

Some of the answers given by the students to their negative opinions about teaching through games are presented below:

ST3: "Teaching with games is a good idea, but it would be more logical if some games were chosen in a way that suits us, that is, in a way that interests us. While games that appeal to me increase my interest, games that do not appeal to me reduce my motivation."

ST4: "While teaching mathematics with games, there are some disruptions in the classroom environment and class harmony."

ST5: "I don't find it very entertaining. It doesn't contribute much to my gaming experience. Because if I don't understand a subject and we don't have time to study, the game has no meaning."

ST7: "They can be a little quieter because there is too much noise in the classroom environment."

ST9: "The classroom environment was loud, but I was not disturbed."

The expressions of the students in the experimental group, where lessons were conducted using the game-based teaching method, reveal positive aspects, such as increased enjoyment of the lessons and a heightened interest in mathematics. However, several points must be considered to use this method effectively. It is necessary to design games that take into account the individual differences of students and to be more careful about classroom management.

In the fourth sub-problem of the research, the opinions of students who received technology-enhanced teaching were examined. The data obtained from the interview form completed by the students were reviewed and edited. The findings regarding the data obtained are shown in Table 15.

Table 15
Opinions of Students in the Technology-Enhanced Group

Themes with Technology-Enhanced	Categories	Frequency (f)	Percentage (%)
Positive Aspects	Developing a Positive Attitude Towards the Course	ST1, ST2, ST3, ST6	% 18,2
	Increasing Interest in the Lesson	ST1, ST3, ST5, ST6, ST7	% 22,7
	Increasing Academic Success	ST2, ST3, ST6, ST7	% 18,2
	Providing learning by attracting attention	ST4, ST10	% 9,1
	Active participation of each student	ST5, ST7, ST10	% 13,6
	Providing Learning with Fun	ST3, ST4, ST8, ST9	% 18,2
Negative Aspects	Noise in the Classroom	ST4, ST9	% 33,3
	Difficulty maintaining long-term attention	ST7, ST6, ST4	% 50
	Bad effect on eye health	ST9	% 16,6

*ST: Student

When Table 15 is examined, it is noted that the interest in the course increases the most among those with positive opinions (22.7%). In negative opinions, difficulty in maintaining long-term attention (50%) was mentioned the most. Some of the answers given by the students regarding their positive opinions about the technology-enhanced teaching method are presented below:

ST1: "It affected us in a good way, because technology is everywhere in our lives."

ST2: "We see the examples live. That's why it's very successful, and I understand it well."

ST3: "It affects very well. I focus better on the subjects."

ST5: "It affects my interest in the lesson well."

ST8: "I have a lot of fun because I love computer games."

ST10: "We can all attend the class. If we can't, our teacher helps, and we understand better."

Some of the answers given by the students to their negative opinions about technology-enhanced teaching are presented below:

ST4: "My friends talk a lot."

ST6: "Our friends talk while the subject is being explained."

ST7: "It affects us badly because our class keeps talking about who will come out."

ST9: "Of course, sometimes our eyes hurt, and it affects the lesson negatively because we cannot listen carefully."

The expressions of the students in the experimental group, where lessons were conducted using a technology-enhanced teaching method, reveal positive aspects, such as increased interest in mathematics and enhanced participation in the lessons. However, several key points should be considered when using this method effectively. It is necessary to take into account the individual differences of students to prevent distractions and promote greater attention in classroom management.

Discussion and Conclusion

Upon examining the research findings, no significant difference was observed between the post-test scores of the groups that used different teaching methods. This finding contradicts some studies (Canevi, 2019; Demir & Bilgin, 2021; Tekin, 2019). In fact, the relevant literature indicates that technology and game-based teaching approaches have a positive impact on student achievement and attitudes in mathematics teaching. Canevi (2019) revealed that GeoGebra-supported computer-assisted instruction significantly increased students' academic achievement and attitudes in functions, function graphs, and analytical geometry. Similarly, in studies examining the effect of game-based teaching on academic achievement, it was determined that the game-based teaching method positively affected student achievement in the 8th grade of secondary school (Demir & Bilgin, 2021) and in the fractions subject of the 4th grade of primary school (Gökbulut & Yücel Yumuşak, 2014). Additionally, technology-enhanced mathematics teaching has been reported to have significant and positive effects on students' academic performance (Tekin, 2019).

The analysis of the retention test scores from the study revealed a significant difference between at least two groups in the teaching methods applied. As a result of the pairwise comparisons, no significant differences were found between technology-enhanced teaching and traditional teaching methods, and between technology-enhanced teaching and game-based teaching. On the other hand, a significant difference was observed in favor of teaching through games compared to traditional teaching methods. These findings reveal that teaching with game-based teaching is an effective method for increasing learning retention. The results obtained also coincide with the studies in the literature that report the positive effects of game-based teaching on retention (Arslan, 2016; Başün & Doğan, 2020; Erkuş & İnan, 2021; Demir, 2016). In the literature, it is seen that game-based teaching has positive effects on learning retention and academic success. Arslan (2016) revealed that game-based teaching on basic geometric concepts and drawings in the 5th grade increased retention. Similarly, a study on factors and multiples found that teaching with games was more effective than traditional methods (Başün & Doğan, 2020). Additionally, research conducted at the secondary school level indicates that game-based teaching has a positive impact on mathematics achievement and the retention of learned information (Demir, 2016; Erkuş & İnan, 2021).

Although no significant difference was found among the groups in post-test achievement scores, the game-based group had significantly higher retention scores than the traditional teaching group. This finding is consistent with previous studies reporting positive effects of game-based teaching on retention (Arslan, 2016; Başün & Doğan, 2020; Demir, 2016; Erkuş & İnan, 2021). Theoretical perspectives suggest that active and meaningful cognitive processing can support longer-term learning and memory (Plass et al., 2015; Sweller et al., 2019). However, these cognitive processes were not directly measured in the present study; therefore, the observed retention advantage should not be interpreted as evidence of a specific underlying mechanism.In this study, the finding that there is no significant difference between technology-enhanced teaching and traditional learning in terms of post-test and retention tests does not align with some previous findings in the literature (Karakış, 2014; Küslü, 2015). In fact, Karakış (2014) states that technology-enhanced teaching on fractions increases academic success; similarly,

Küslü (2015) reported positive effects on the use of prisms. However, students' prior access to technology, familiarity with digital learning environments, and adaptation to different instructional approaches were not measured in the present study. Therefore, these factors cannot be used to explain the absence of a significant difference.

No significant difference was found between the technology-enhanced and game-based teaching groups in terms of academic achievement. Previous literature indicates that learning outcomes in digital and game-based environments may be influenced not only by the medium itself but also by instructional and design characteristics (Clark et al., 2016; Mayer, 2024). However, pedagogical design was not examined as an explanatory variable in the present study; therefore, this literature is considered as a broader interpretive context rather than as a direct explanation for the observed result.

Although no significant difference was found in post-test achievement, students' qualitative responses indicated generally positive perceptions of both experimental teaching approaches. Students in the game-based teaching group reported increased interest, enjoyment, and perceived learning benefits, while students in the technology-enhanced teaching group emphasized increased interest, improved understanding, and greater classroom participation. These findings reflect students' perceptions of their learning experiences and should not be interpreted as evidence of directly measured changes in attitudes, engagement, or achievement.

The students in the experimental groups stated that both teaching approaches supported learning by having fun and increased their interest in the lesson. However, it has been observed that activities that do not appeal to all students in teaching through games can force classroom harmony. In technology-enhanced teaching , it has been observed that some students may struggle to maintain sustained attention over extended periods. These findings are consistent with broader theoretical literature suggesting that the effectiveness of game-based and multimedia learning environments may depend on how learning activities and instructional materials are designed and implemented (Plass et al., 2015; Mayer, 2024).

When the quantitative and qualitative findings are considered together, the student views provide explanatory context for the patterns observed in the achievement and retention results. Although the three groups did not differ significantly in their immediate post-test achievement, the game-based teaching group demonstrated significantly higher retention scores than the traditional teaching group. Students in the game-based teaching group emphasized enjoyment, increased interest, and reinforcement of learning, suggesting that these learning experiences may have contributed to the longer-term retention of what was learned rather than producing an immediate achievement advantage. At the same time, students reported classroom noise, difficulties with classroom harmony, and differences in how much games appealed to individual learners, which may help contextualize the absence of a significant post-test advantage. Similarly, students in the technology-enhanced group reported increased interest and participation but also described difficulties in maintaining sustained attention and classroom distractions. These experiences may provide contextual insight into why technology-enhanced teaching did not result in a statistically significant advantage in either post-test achievement or retention. Thus, the qualitative findings do not merely supplement the quantitative results but help elaborate on the learning experiences that may underlie the observed quantitative patterns. Since qualitative data were collected only from the experimental groups, however, these interpretations should be regarded as complementary explanatory evidence rather than direct qualitative comparisons with the traditional teaching group. However, the interview questions did not specifically examine the mechanisms underlying long-term retention. Therefore, although the qualitative findings provide some contextual support for the quantitative results, they cannot fully explain why the game-based group showed higher retention scores.

Limitations

Several limitations should be considered when interpreting the findings of this study. First, the quantitative sample consisted of 51 fifth-grade students, with 17 students in each group. Therefore, the relatively small sample size may limit the statistical power of the analyses and the generalizability of the findings to broader student populations. Second, all participants were drawn from a single public secondary school. Consequently, school-specific characteristics, classroom context, and student profiles may have influenced the findings, and the results should therefore be generalized to other educational settings with caution. In addition, the sample was selected through a non-random, accessibility-based approach, which further limits its representativeness. Finally, the qualitative data were collected only from students in the two experimental groups; therefore, the qualitative findings provide explanatory information about students' experiences with game-based and technology-enhanced teaching but do not allow direct qualitative comparison with students in the traditional teaching group. In addition, the interview questions primarily focused on students' general experiences and perceptions rather than specifically probing the mechanisms underlying long-term retention. Therefore, the qualitative findings could not fully explain the mechanism behind the higher retention scores observed in the game-based group. Future studies involving larger, more diverse samples from multiple schools and educational contexts may provide stronger evidence of the generalizability of the findings.

Recommendations

As a result of the research, the following suggestions were made:

Game-based teaching may be considered an alternative to traditional mathematics instruction, given the higher retention scores observed in the game-based group in the present study. Students in this group also reported generally positive perceptions of the approach, particularly regarding interest and enjoyment.

Technology-enhanced teaching may be used to support students' interest and participation in mathematics lessons. However, because some students reported difficulties in maintaining attention, such applications should be planned with appropriate classroom interaction and pedagogical support.

In order to minimize the noise and distraction problems observed in game-based teaching and technology-enhanced teaching methods, it is recommended to review classroom management strategies and activity planning, and to organize learning environments according to the different interests and needs of students.

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